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Identifying theoretical foundations for the integration of children's literature and mathematics : two case studies.

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IDENTIFYING THEORETICAL FOUNDATIONS FOR THE INTEGRATION OF CHILDREN'S LITERATURE AND MATHEMATICS: TWO CASE STUDIES

A Dissertation Presented

by

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DEDICATION

To my husband Michael who helped me find my voice as a writer,

and to our children Emma and Isaac.

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ABSTRACT

IDENTIFYING THEORETICAL FOUNDATIONS FOR THE INTEGRATION OF CHILDREN'S LITERATURE AND MATHEMATICS: TWO CASE STUDIES

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Integrating children's literature and mathematics is a popular strategy used by many teachers to meet the Standards for mathematics education as outlined by the National Council of Teachers of Mathematics (NCTM). At this time literature on integrating math and literature focuses on books, lesson ideas and students' responses. What led teachers to decide to integrate these two subjects, and an articulated theoretical grounding for this strategy, is largely absent in current literature.

The purpose of this study is to answer the following questions: How does a teacher come to implement integrating children's literature and mathematics as a strategy for designing mathematics instruction?, and Is integrating children's literature and mathematics a teaching strategy that is constructivist and/or brain compatible? Constructivist theory informs us that individuals construct and co-construct knowledge; each of us builds or creates knowledge from our experiences. What we learn is directly related to what we experience and the interplay between old and new experiences; how we make meaning. Brain-based learning theory weaves together knowledge of how the human brain functions and the design of

learning experiences that are brain compatible. I chose these two theories in particular to identify connection between practice and theory and because they are widely recognized by educators as grounding for effective educational practice.

To answer the two research questions, I designed two case studies. Each case study focuses on a veteran elementary school teacher in the process of integrating children's literature and mathematics as a strategy for designing mathematics instruction. Primary sources of data for the case studies are interviews with the teachers about their decision-making process, and the observation and analysis of integrated math and literature lessons for theoretical grounding.

Based on the data collected I found that the two teachers who participated in this study each came to integrate children's literature and mathematics through participation in professional development. The integrated children's literature and math lessons I observed and analyzed met the theoretical criteria for constructivism *and* brain compatible learning. Use of children's literature and the teachers' lesson design are key aspects of theoretically grounding lessons that integrate children's literature and mathematics.

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CHAPTER I

INTRODUCTION

Introduction

Integrating children's literature and mathematics is a popular strategy used by many teachers to meet the Standards for mathematics education as outlined by the National Council of Teachers of Mathematics (NCTM). For the purpose of this dissertation children's literature is defined as any book created to entertain or inspire children. This definition includes all genres of well-written literature, and wordless picture books designed for very young children.

This dissertation is designed to answer two questions about the integration of children's literature and mathematics. The first question is: "How does a teacher arrive at the decision to implement integrating children's literature and mathematics as a strategy for designing mathematics instruction?" The second question posed: "Is integrating children's literature and mathematics a teaching strategy that is theoretically grounded in either one or both of constructivist or brain-compatible learning theories?" Using a case study approach these two questions are examined in-depth.

Statement of the Problem

As an elementary school teacher, I used children's literature to introduce math ideas and frame problem-solving situations to make math more interesting for my students and more approachable for me. My students participated much more actively in math lessons which involved a story than those that came from a workbook. I enjoyed them because I was more comfortable with reading than math and felt I'd found a way to make more sense of math and get beyond a textbook. Using literature also offered me a way to integrate curriculum in a way I believed was more effective and meaningful. I saw that math was a part of daily life and my students experienced this through the characters in the books we read together.

Many other teachers are integrating literature and math in their classrooms (Bertheau, 1994, Burton, 1996, Curcio, Zarnowski, & Vigliarolo, 1995, Litton, 1995). In sharing their classroom experiences these teachers share their successes (increased student interest in math time, books that were particularly appropriate for math adaptations, lessons that could be designed from specific books...) and their next steps. It is inspiring to read what others do but I want to know if what they are doing is more than a "great idea" and how they arrived at choosing to integrate these two subjects. Currently the literature on integrating math and literature focuses on book titles, lesson ideas and students' responses. This study explores how two teachers chose to integrate math and literature, and to explore what theoretical foundation there may be for integrating math curriculum with children's literature based on lessons these teachers teach.

Statement of Purpose

The purpose of this study is to answer the following questions: 1. How does a teacher arrive at the decision to implement integrating children's literature and mathematics as a strategy for designing mathematics instruction?, and 2. Is integrating children's literature and mathematics a teaching strategy that is constructivist and/or brain compatible? Constructivist theory informs us that individuals construct and co-construct knowledge; each of us builds or creates knowledge from our experiences. We seek to make sense out of new experiences by relating them in some way to what we already know; we seek to make sense and connections. What we learn is directly related to what we experience and the interplay between old and new experiences; how we make meaning. Brain-based learning theory weaves together knowledge of how the human brain functions and the design of learning experiences that are brain compatible.

Approach

To answer my two research questions I designed two case studies. Case study methodology allows for in-depth examination of a particular issue or topic (Feagin, Orum, & Sjorberg, 1991). Each case study focuses on one elementary classroom teacher who recently integrated children's literature and mathematics as a strategy for teaching math. The case studies include several data sources. To answer how a teacher arrives at the decision to implement integrating children's literature and mathematics as a strategy for designing mathematics instruction I interviewed both teachers about their personal experiences with math as a student, their approaches to teaching mathematics, and why they chose to integrate literature and mathematics. I transcribed these interviews and analyzed the responses from both teachers. I looked for commonalities and differences between their paths toward integrating literature and math. In addition to the interviews each teacher kept a journal about the integrated literature and math lessons. These contained some reflections that further informed me about their decision to integrate literature and math.

To answer my second research question, "Is integrating children's literature and mathematics a teaching strategy that is theoretically grounded in either one or both of constructivist or brain-compatible learning theories?", I used the following data sources: field notes from observations of lessons taught by the teachers which integrate literature and math, the teachers' journals with planning notes and reflections on the lessons, conversations with the teachers about the observed lessons, and research into constructivist and brain-compatible learning theories. I analyzed each of the observed lessons using an articulation of constructivsm put forth by Pirie and Kieren (1992) and elements for brain compatible learning as outlined by Ross and Olsen (1995) and Llyod (1995). I then looked for themes among the individual lessons to conclude whether or not the lessons are constructivist and/or brain-compatible.

Rationale and Significance of the Study

At this time, the strategy of implementing children's literature and mathematics has been described purely in practical terms in the literature. Teachers and students offer their experiences, many of which appear very positive. I'd like to examine this strategy against the backdrop of two articulated theories on how people learn. Without some support or direct connection to genuine learning theory, integrating math and literature can be relegated to just being "a great idea" or the next/last passing educational fad.

One broad rationale for this study is that it will aid researchers to gain insight into how teachers select and implement a new teaching strategy in their classrooms. This study focuses on integrating children's literature and mathematics as a specific strategy. Articles and books currently available describe teachers already engaged in integration. This study will explore how teachers plan to integrate and what moves them to try integrating literature as a teaching strategy. Shifter and Fosnot (1993) compiled stories describing teachers examining and relearning math concepts as learners themselves. This book provides insight into how several teachers responded to publication of NCTM's Standards and made efforts to change their teaching practice in mathematics. More recently Schifter (1996) edited two volumes of stories by teachers discussing themselves as learners and how they have changed their teaching practices. These books address in a general way the topic of teachers making change in their mathematics teaching; this study focuses specifically on bringing literature into the mathematics class as a change in mathematics teaching.

Another rationale is that it is important to look at integrating math and literature lessons from a theoretical perspective. Teacher resources on integrating children's literature and math such as Read Any Good Math Lately? (Whitin & Wilde, 1992), Math and Literature (Burns, 1992b), It's the Story That Counts (Whitin & Wilde, 1995), and a regular column "Literature Links" in *Teaching Children Mathematics* focus on recommending children's books to use for designing lessons integrating literature and math, and teachers sharing how they used a particular book for math learning. These books and articles offer ideas and possibilities for changing math teaching through literature, but they consistently leave out any connection of this teaching strategy to theories about how children learn. I investigated the links between integrating children's literature and constructivist, brain-compatible learning theories.

Background of the Problem

Integrating curriculum is a teaching strategy that is popular, but in need of research (Kain, 1993). Kain sets out four broad questions to consider about integrating curriculum. These questions include: 1. Why integrate curriculum?, 2. What is integrated?, 3. Who gains from integrated studies?, and 4. What are the differences between integrated learning and traditional learning?

Three of these questions are addressed in the content of this dissertation. The second question stems from the interchangeable use of terms such as integrated, theme-based, and interdisciplinary. One area of research he specifically proposes is clarifying what is meant by the term "integrated." For the purposes of this dissertation integrated refers to lessons that use and/or develop skills from more than one content area in a seamless fashion. In an integrated lesson student learning is embedded in experience from several disciplines as a whole.

Jongsma (1991) suggests that because mathematics is a communication system much like language, math needs to be looked at from a whole language perspective. Goodman (1992), renowned for his work in whole language, wrote the foreword to Whitin and Wilde's Read Any Good Math Lately? He states here that whole language has provided many teachers with a philosophy for designing whole, authentic [integrated] learning experiences. He states that while many teachers have found ways to integrate curriculum, particularly language arts with social studies, language arts with science, and expressive arts throughout the curriculum, math has often been left out. He suggests that literature is a 'bridge' between math and integrated, whole learning. Applying the whole language philosophy to math makes sense because concept learning is done in context (Baker & Baker, 1991). Brown (1991) suggests that to effectively adapt the whole language practices of learning in a "meaningful, relevant and holistic manner" for math we should adopt the term "whole concept". Whole concept mathematics is focused on problem solving that is real and meaningful giving students a context to practice many skills (not just arithmetic). Literature provides this context.

According to Norton (1995) , "Literature entices, motivate and instructs." (p. 4) Burns (1992b) also suggests that literature is motivating, particularly in math lessons. Using literature to teach math is a way of helping students link math and the ideas in books. Rothlein and Meinbach (1991) suggest that literature links lessons with reality by adding perspective and dimension to the concepts taught. As Welchman-Tischler (1992) says, teaching math through literature is a way of achieving a whole that is greater than the sum of the parts. This dissertation is focused on identifying a theoretical background for these statements.

Overview of the Dissertation

This dissertation is organized into five chapters. The first is an overview and introduction to the dissertation including a statement of the problem, statement of purpose, and rationale for the study. In the second chapter, literature on integrating literature and mathematics, children's literature and resources, constructivism and brain compatible learning are reviewed. Chapter three describes the design of the study. The fourth chapter presents the data collected and analyzed to answer the two focusing questions of this study. In the fifth chapter conclusions are drawn about the data analysis and numerous recommendations for further research are suggested.

CHAPTER II

REVIEW OF THE LITERATURE

This chapter provides a synthesis of recent published literature on integrating children's literature and mathematics and an articulation of the learning theories central to the study. The theories explicated are constructivism and brain-based learning.

Studies in Integrating Children's Literature and Mathematics

Using children's literature provides a foundation for reaching the goals and addressing the standards set out by National Council of Teachers of Mathematics (NCTM). Mathematical activity and exploration inspired by literature provides children with opportunities to value mathematics, solve authentic problems while building confidence in their ability, and communicate and reason mathematically. The Standards were written in response to nationwide calls for reform in mathematics education due to consistently poor math test results (Frye, 1989) and recognition that students need a mathematics curriculum that prepares them for participation in the ongoing shift from an industrial society to an information society (Johnson, 1990).

The Standards document outlines goals for students that expand mathematics learning beyond the traditional emphasis on arithmetic. The cornerstones of the NCTM document are: Mathematics as Problem Solving, Mathematics as Communication, Mathematics as Reasoning, and Mathematical Connections (House, 1990). In addition to the four cornerstones, the Standards document outlines five broad goals for the mathematical education of all children: "(1) that they learn to value mathematics, (2) that they become confident in their ability to do mathematics, (3) that they become mathematical problem solvers, (4) that they learn to communicate mathematically, and (5) that they learn to reason mathematically" (NCTM, 1989, p.5).

Romberg (1993) states that the Standards are the result of scholarly review and discussion, but very little research is actually cited in the document about how people learn mathematics. The Research Advisory Committee of NCTM (1988) also states that there is a significant research base for the Standards but admits that more needs to be done to articulate this base to those involved in mathematics education. This process of articulation is addressed in the draft copy of Standards 2000 (NCTM, 1998) through numerous citations and a lengthy references list. What is clear in documentation about the creation of the current Standards is that many educators and mathematicians were involved in the creation, revision, and implementation of the published document.

Mathematics is an integral part of our daily lives and is also an integral part of the stories we read and tell (Larson, 1992). Every children's book contains some mathematical element or concept that can serve as a springboard for discussion about mathematical ideas, or as the basis for activities which develop students' mathematical understandings (Radebaugh, 1981, Cooper, 1982, Meconi & Moss, 1991, Braddon, Hall & Taylor, 1993). Many books appear on the surface to contain no mathematics but further examination always reveals that concepts such as time, measurement, geometry or money are a component of the story. Numerous authors state that children's literature provides a meaningful context for mathematics teaching and learning (Whitin, 1993, Lewis, Long, & Mackay, 1993, Whitin, & Gray, 1994, Gongs, 1991, Hopkins & Dorsey, 1992).

Literature increases children's interest and achievement in mathematics (Jennings, Jennings, Richy and Dixon-Kraus, 1992). Hong (1996) describes a study he conducted with fifty-seven kindergarten children that was designed to examine the effect of implementing mathematics lessons which were integrated with a literature selection versus mathematics lessons which did not use literature. His study was organized around two broad questions:1. Could using children's literature influence children's interest in mathematics? and 2. What is the effect of integrating literature on math achievement? He found that children taught with lessons using literature chose to spend more time in the math corner of the classroom and expressed liking math more than children who had traditional lessons. There was no significant difference in achievement scores but Hong suggests this could be due to the small size of the population and the fact that all children in the study had the same math practice sheets for homework.

Integrating literature and mathematics helps students see connections between school learning and real life. To further these connections teachers can use literature to develop activities that are interesting and relevant, and encourage students to build on previous learning (Sheft, 1989, Jamar & Morrow, 1991). Books are more engaging, attractive, and motivating than traditional math texts, which leads children to be more enthusiastic about learning (Burns, 1993, Young & Vardell, 1993). Using children's literature as a source for real-life math problems catches the attention of students and enlivens math classes (Cohn & Wendt, 1993). Burnett and Wichman (1997) say the reason for integrating curriculum is to provide students with learning opportunities that are more like the real world (since the world is not arranged into neat subject matter experiences). They suggest that using literature for math lessons is a 'natural way' to integrate learning because children love to hear stories and there are many possibilities for students to participate and interact with the concepts in a book.

Teachers using children's literature as a springboard for math lessons report changes in attitude, mathematical understanding and interest in learning mathematics. The following quote from Amy, an eighth grader, is an example of a student voicing such changes. Amy wrote the following in her journal after a fraction lesson using the story Tom Fox and the Apple Pie (Watson, 1972)

> "I wish my math teacher had read math books to me. That's the first time I've really understood why the smaller number is worth more (i.e. why 1/2 is greater than 1/5, even though five is greater than two). Are there any more books that teach math? I learn better that way." (Mills, O'Keefe and Whitin, 1996, p.4)

Conaway and Midkiff (1994) state that using literature helps students communicate mathematically. They use fractions as an example and offer numerous books to share with children that would both set the stage for extension activities and help them see that fractions are used in our daily lives. Realizing that math is a part of our daily lives is a key for many students finding some meaning in mathematics; some reason to learn math. When problems are posed that students can relate to, such as those experienced or inspired by story characters, they demonstrate higher levels of performance (Karp, 1994).

More meaningful problems lead to more successful problem solving by children and using literature provides a context for strengthening and connecting links between content areas and other learning expectations (Richardson & Monroe, 1989). Smith (1995a, 1995b) describes her efforts to integrate social studies and math. She found that children's literature provided the links needed to build her lessons. She selected books (The Patchwork Quilt (Flournoy, 1985), Jumping the Broom (Wright, 1994), and Sweet Clara and the Freedom Quilt (Hopkinson, 1993) with quilting as a central theme and designed lessons which focused on patterns and geometry. She also discussed family relations, history, and cultural traditions with her class in addition to the math concepts. Stewart (1997) cites numerous book she finds are effective for linking mathematics learning and other aspects of the curriculum including health, social studies, and diversity awareness.

Recognizing the potential for making learning connections Harris (1997) chose the Franklin books (Paulette Bourgeois and Brenda Clark) as the basis for a series of problem-solving lessons early in the school year. Franklin is a turtle who solves life problems, often with the help of his friends. Harris used these stories to give her first and second grade students opportunities to work together in small groups which helped foster a sense of community in her class. She encouraged them to communicate mathematically by working collaboratively to design a solution, write about their solutions and use a Franklin puppet to act out their solution to the problem. The children were excited to share their solutions to the Franklin stories. Harris was thrilled to see that these experiences carried into other class experiences. Where children previously had difficulty solving a simple problem independently, they were now able to come up with many solutions and had the vocabulary, collaborative, and thinking skills to create a solution.

Working with children ranging in age from eight to ten Karp, Allen, Allen and Brown (1998) designed integrated literature and math lessons around the theme of literature with strong female characters (whom they call feisty females). They read the books they selected aloud to the whole class, discussed literary elements, and then asked the students what mathematics they saw in the story. Student response guided the direction of mathematics explorations. The teachers were responding to research which suggests that girls tend to lose interest in math as they get older. It is their hope that using literature with feisty female characters and connecting math learning to these characters might maintain or increase girls' participation in mathematics.

Maryann Wickett (1998), a third grade teacher, used Saturday Sanchoco, by Leyla Torres, to engage her students in learning about division. In the story, which is available in both Spanish and English, a grandmother and her granddaughter go to the market to get the ingredients to make sanchoco with a dozen eggs but no money. Wickett read the story aloud to her students; at the end one student asked if the characters had traded the eggs for the foods they needed. The second time she read the story she encouraged the children to keep track of what the eggs were traded for. This activity led to a discussion about bartering and how things are valued. She then reminded students that in the story the items bought at the market were evenly divided between the two characters. The direction of their exploration then became focused on the variety of ways the foods could be evenly divided. In the process of this activity Wickett was able to see a variety of levels of thinking. Some children cut foods into parts to make baskets come out even while others designed a variety of equivalents to make the baskets equal. Throughout their exploration children got firsthand experience with recognizing the variety of goods that can have the same value as well as how to divide. They also learned that sometimes you can get what you want or need through a means other than money.

Burnett and Wichman (1997) designed an action research project to examine the effects of integrating children's literature and mathematics on students' ability to connect school math to real life and decrease math anxiety. They focused on the second graders in their school, a population of 558 students. To determine the effect of lessons which used literature to place math concepts in real life situations, Burnett and Wichman gave students a math skills pre and post test, and also administered a survey to determine levels of math anxiety. After five weeks of lessons integrating literature and math they found that student skills significantly increased. The survey revealed that students felt more comfortable about doing math, and teachers could see and hear the children's excitement and interest in math increase. Students asked when they were going to "do math" when a story was used for math time; they also began to spontaneously share times and places where they used math at home, play, or in other aspects of the day.

In addition to their findings on the children's increased skill and confidence in math, Burnett and Wichman discovered that using math and literature is a strategy that needs to be used flexibly. In their study they committed to two math and literature lessons per week. They found approaching integration this way often did not work as students were sometimes not ready for the concepts in the selected books and they expressed difficulty finding books for some concepts. They recommend using the literature as it makes sense for children's concept development and when a realistic match can be made between a literature selection and a math concept.

Children's Literature Selection and Resources

Numerous books and articles are available to support teachers' selection of children's books for mathematical lessons. These resources offer a wide range of information including criteria for choosing books; bibliographies (often annotated) listing books directly related to specific math concepts; teaching guides which model how to use individual books with follow-up activities, and teachers sharing how they have implemented literature in their math classes. Two broad approaches for implementing math-literature lessons emerge from my review of currently available resources: a holistic approach where classroom planning is integrated thematically through a math concept and a more focused approach where stories are introduced to a class for the purpose of developing a particular concept.

Whichever approach a teacher takes in planning, choosing books carefully is essential. Spann (1992) advocates simply choosing books that interest children. Her suggestion supports the notion that all books have some mathematical concept but in order to develop specific math concepts teachers need to select books thoughtfully. Harsh (1987) strongly recommends that along with interest or appeal, books should be appropriate for children's developmental levels. This is particularly important for young children who need clear representations of concepts as their mathematical understandings are just forming.

Jacobs and Rak (1997) offer a list of children's books and possible math lessons or activities to develop from these books. Each one has the potential to be as rich as the previous examples. They state, as do other authors, that literature provides an authentic context for mathematics learning, opportunities to solve real-life problems, and is a meaningful tool for teaching mathematics.

There are numerous books written specifically for the purpose of describing or developing a mathematical concept. <u>26 Letters and 99 Cents</u> by Tana Hoban, uses photographs of money to show young children coins representing various values up to ninety nine cents. The book flips to become an alphabet book. Both sections are visually crisp and bright, representing money and the alphabet in a simple, uncluttered style.

Bruce McMillan's <u>Eating Fractions</u> also uses photography to illustrate foods cut into fractions. Each food is shown whole and then cut into a fraction, which is clearly labeled. Two boys are featured throughout the book sharing the food fractions. At the end of the book McMillan provides recipes to make the foods shown. Using photography emphasizes the real life need for using fractions in our daily lives. This real life connecton is reinforced by needing the fractions to measure ingredients for recipes listed at the end of the book.

How Much is a Million and If You Made a Million, both written by David M. Schwartz and illustrated by Steven Kellogg, focus on large numbers by putting them into contexts which children can both relate to and understand. Each of these books includes a discussion at the end for adults, describing how the author figured out how long it would take to count to a million and the height of a stack of dollar bills. These descriptions are helpful because they describe one approach to making large numbers accessible. They also model problem-solving processes giving students a real life application for using math outside the classroom. Adults may invite children to try other ways of exploring large numbers beyond what Schwartz did or to try out his approach and see if they come to the same conclusion.

In addition to individual books written with math in mind, three children's book series are currently available with the objective of exploring math concepts through children's books. "Marilyn Burns Brainy Day Books" is a developing series which includes real stories with suggested follow-up activities at the end. One example from the series is A Cloak for the Dreamer, by Aileen Friedman. This story is about a tailor with three sons, each set with the task of creating a cloak. The cloak each son designs and constructs will determine whether or not he may join his father's business. The two elder sons do wish to become tailors like their father, but the youngest wishes to travel and see the world. Each cloak will determine their individual future. The story is told with rich, descriptive language and caring among the characters. The two older sons become tailors as they wish. The third makes a beautiful, yet impractical cloak; his father recognizes his creativity and supports his son's desire for a different career.

There is a tremendous amount of geometry and measuring involved in sewing. This aspect is focused on in the notes written to parents, teachers and other adults at the end of the story. Burns also reminds adults that while A Cloak for the Dreamer has a lot of mathematical ideas, the primary goal of sharing the story is to engage, delight, stimulate and encourage children to develop their love of reading. She keeps the focus of sharing a story on the book and responding to children's reactions rather than setting them on a predetermined learning track while reading. In other words, she suggests allowing the book to be a springboard for the math without turning the story itself into the math lesson.

Another series designed to integrate children's literature and math is the "Hello Math Reader" books. These books are written on four levels for ages three through nine. Books in the series focus on one math concept and use very simple language and characters to create a story that shows a mathematical concept in some context. An example from the preschool level is Monster Math (Maccarone, 1995). At first glance this book is a very simple counting book, but it is actually introducing the basic concept of subtraction. The book begins with twelve monsters. One at a time the monsters leave for various reasons until the book ends at zero. Another example from this series, Even Steven and Odd Todd (Cristaldi, 1996), is written for first and second graders. The story is contrived so that everything in Even Steven's life is even while everything in his cousin Odd Todd's life is odd. There is some conflict as the two interact, Steven's even set -ups are constantly disrupted by his cousin adding or taking away something, making it odd.

Each of the books in the "Hello Math Reader" series includes a description of the mathematical concept central to the story and activities and games, designed by Marilyn Burns, which provide opportunities for children to practice the particular concept presented in the story. These books seem well intentioned, but there are so many books that naturally include the same mathematical concepts it seems more effective to skip the contrived story and adapt the activities to a genuine literature selection.

A third series recently available is "MathStart" (Murphy, 1998). This series is designed in three levels, each focuses on a variety of math concepts. Notes are included at the end of each book which pose questions for adults to ask children while reading, and suggestions for how to help children see math concepts in the world around them. The series is accessible for children but the language and illustrations are contrived.

An example from the MathStart series, <u>Jump, Kangaroo, Jump!</u>, is written to focus on fractions. This story takes place at a camp where the animal characters are engaged in a competition. The illustrations are unappealing; the kangaroos look like dogs and the color palette is very muted. The fractions are written in numerical form both in the context of text, and separately as captions for illustrations. It is obvious this book is designed for instruction, not entertainment or inspiration.

Aspects to examine when selecting any mathematical concept books are: connection between text and illustrations, clarity of illustration and text, inclusion of concepts that are developmentally appropriate and using cardinal and ordinal numbers interchangeably (Ballenger, Benham, & Hosticka, 1984). An example of mixing ordinal and cardinal is Maurice Sendak's <u>One Was Johnny: A Counting Book</u>. Numerous characters enter Johnny's house in an order suggesting ordinal position but only cardinal numbers are used in the text. For example the text says, “4 was a dog who came in and sat.” To be accurate the text should say “*Fourth* was a dog who came in and sat.” Sendak’s use of “4” for “fourth” could create confusion for young readers who are still developing math and language skills.

In <u>One Duck, Another Duck</u>, by Charlotte Pomerantz, the text and accompanying illustrations present counting in a confusing manner; the connection between the two is inappropriate. In this story a young owl is flying with his grandmother when he spots some ducks swimming on a pond. He says, ”One duck, another duck...” His grandmother tells him to count, “One, two, three and so on.” In the pages that follow the text reads “One duck, another duck’ while the illustration shows two ducks, then “Two ducks, another duck” while the illustration shows three ducks. This pattern continues until ten ducks are showing. The use of “another” after each number is confusing, as are the illustrations consistently showing one more duck than the number stated in the text. Because the illustrations clearly represent the increasing number of ducks this book could be used for a counting lesson. Discussing the text of this book with childeren has the potential to engage students in constructing their understanding of why we use specific counting language.

<u>Constructivism</u>

In an effort to uncover an articulated theoretical basis to support both the Standards’ recommendations and integrating children’s literature and mathematics as an approach to implementing them, I read research about mathematics teaching and learning, particularly publications put out by NCTM or cited in NCTM articles. Two broad theoretical constructs consistently emerged from reading this research which I believe provide a theoretical perspective for integrating children’s literature and mathematics as well as support for the goals set out in the Standards. These two recurring constructs are constructivism and brain-based learning. These constructs are linked by the recurring, shared theme of making meaning. Constructivism and brain-based learning address the process of meaning-making for each learner, both as an individual and as a member of a community.

Schifter (1993) states that the Standards codify a vision of mathematics based on two decades of research converged with societal change. In a traditional math class students are told how to perform algorithms and given time to practice getting the right answer (Burns, 1992a). Romberg (1990) suggests that teaching mathematics this way is a result of viewing mathematics as a subject with a collection of facts to absorb. He points out that society's shift from industry to information and the availability of calculators and computers requires a broader view of mathematics teaching and learning. Traditional classes are based on a transmission or absorption theory of teaching and learning (Clements and Battista, 1990) whereas the Standards are based on a constructivist model. These two theories are opposite in describing how learning occurs. Teachers using a transmission model offer learning to students as a fixed package. If students follow the teacher's directions and arrive at the correct answer then they have learned the material. In contrast, constructivism is described as an interaction between the student's prior knowledge, beliefs and new information (Ball,1988). Learning mathematics in a constructivist view requires students to actively construct knowledge rather than passively receive it (Davis, Mahar, & Noddings, 1990). A constructivist also believes that knowledge is constantly updated through interaction with one's environment (Noddings, 1990).

Numerous educators describe approaches to mathematical teaching and learning which are conducive to fostering the constructivist model and meeting the goals set out by NCTM (Griffiths & Clyne, 1988, Whitin, Mills, & O'Keefe, 1990, Edwards, 1990, Schifter & Fosnot, 1993, McKeown, 1990, Baker & Baker, 1991 and Baker, Semple, &, Stead, 1990, Stix, 1994). Several elements are consistently identified in these descriptions: developmentally appropriate activity, learning in context, meaningful and purposeful exploration, a multimodal approach and a positive learning environment. Baker, Semple and Stead (1990) suggest a model for math learning that includes all these elements. Their model draws a comparison between traditional language learning and traditional math learning. They turn the traditional model, which has learning starting with meaningless pieces, upside down. As in whole language math should start whole; with a problem to solve rather than an algorithm to perform.

Children need opportunities to invent their own procedures for developing algorithms rather than follow those outlined by a teacher (Kamaii, Lewis and Livingston 1993). Children following a teacher's algorithm learn rules but not mathematics. Traditional math teaching focuses on arithmetic, viewing math as the science of numbers. But math is more than numbers. Whitin and Wilde (1992) define mathematics as"... a human endeavor, a communication system devised by people to meet their culture's changing needs and interests."(p. 38) This definition suggests that math is something a person creates with others, it is something one constructs. It is also something that takes imagination (Phelan, 1991).

Constructivism is an epistemological theory that in the last ten years has become the focus of research and discussion driving change in mathematics education (Davis, Mahar and Noddings, 1990). Epistemology is a branch of philosophy focused on "how we know what we know and " the logical bases for ascribing validity or truth to what we know" (Goldin, 1990, p.32) Constructivism is based on the philosophical viewpoint that "...human beings have no access to reality..." Rather we construct our knowledge of the world from our perceptions and experiences, which are themselves mediated through our previous knowledge. Learning is the process by which human beings adapt to their experiential world." (Simon, 1995, p.115).

Confrey (1990) defines constructivism as "... a theory about the limits of human knowledge, a belief that all knowledge is necessarily a product of our own cognitive acts. We can have no direct or unmediated knowledge of any external or objective reality. We construct our understanding through our experiences, and the character of our experience is influenced profoundly by our cognitive lenses." (p. 108).

The common thread in both of these definitions is experience. What we learn is directly related to what we experience and the interplay between old and new experiences; how we make meaning. In other words how we connect new experiences with previous experiences and how we revise what we think we 'know' as we encounter new situations. Another shared aspect is the implication of activity. Individuals construct; each of us builds or creates knowledge from our experiences. We seek to make sense out of new experiences by relating them in some way to what we already know; we seek to make sense and connections. Prawat (1995) states that while there may be many interpretations about what constructivism means there is agreement on two key aspects: " Learning is a process of active construction and that process results in qualitative change in understanding." (p. 48). How we set about this process has been the topic of research and reflection by educators, philosophers and psychologists. Three theorists are most consistently cited as foundational figures in constructivism; Piaget, Dewey and Vygotsky (Ginsburg, 1981).

According to Piaget,"...all knowledge is a construction resulting from the child's actions." (Wadsworth, 1984, p.22). Piaget classified himself as a genetic epistemologist, someone concerned with the science of how knowledge is acquired. His initial academic training was in biology, which influenced his later work as he moved on to the fields of philosophy and psychology. Through extensive research on mollusks Piaget concluded that biological development was due to environmental factors in addition to maturation and heredity. His experience with the mollusks and the conclusions he drew from researching them became integral to his view of cognitive development as essentially a process of adapting to one's environment and extension of biological development (Wadsworth, 1996).

Kuhn (1992) states that Piaget used a metaphor of the child as developing philosopher or logician or scientist. This metaphor both echoes his personal experience of meaning making and concisely describes his view of development. In Piaget's theory cognitive development occurs naturally as a result of experiencing the world and reflecting on one's experiences (Case, 1992). In the early stages of life many experiences are concrete, based on interaction with objects. As one develops experiences gradually take on a more abstract role including active engagement and reflection in addition to concrete interactions. According to Piaget learning is secondary to development and is most effective when learners are actively involved (Mackay, 1983). Active involvement is key to the idea of constructivism, for it places individuals in control of their own cognitive development or makes them partners in co-construction.

Piaget articulated four basic concepts to describe intellectual development: schema, assimilation, accommodation, and equilibrium. Schemata (plural for schema) are the cognitive structures that we use to organize our understanding of our environment. Each schema represents a concept or category. As a person develops his/her schema are continually refined. Assimilation is when a person places new information into his or her preconceived notions about the world. Accommodation is the process of revising a preconceived notion based on a new experience resulting in creation of a new schema or revision of an old one. Equilibrium is, "a state of balance between assimilation and accommodation" (Wadsworth, 1996).

Bryant (1983) suggests that equilibration, the process of moving from disequilibrium to equilibrium is the heart of Piaget's theory. Disequilibrium is triggered when a cognitive conflict arises based on a person's expectations or predictions; i.e. when there is a discrepancy between expectation and actuality. Construction is the process of assimilation and accommodation through an individual's experience with the world (Singer & Revenson, 1978). This process is regulated through equilibration.

Piaget's work focuses on individual intellectual construction without answering questions of how social or cultural influences affect construction (Saxe, Gearhart, Note & Paduano, 1993). Yackel, Cobb, Wood, Wheatley, and Merkel (1990) state that children do create and construct their own mathematical understandings, but not in isolation. They suggest that collaborating with others causes students to interact and verbalize ideas as part of their construction process which broadens and deepens their understandings. This suggestion is directly supported by the work of Dewey and Vygotsky and others such as Noddings, Simon, Cobb, Ernst, and Yackel who apply constructivism to mathematics education.

Dewey wrote, "Education is not an affair of 'telling' and being told, but an active and constructive process" (Dewey, 1916/1966, p.38). His approach to education/curriculum, often simplistically referred to as "learning by doing", is founded on the idea that learning occurs when students are actively engaged in socially purposeful activity that has meaning to them. A key component of construction is the communication between individuals engaged in the learning process. He suggests that meaning-making (learning) occurs when lessons are developed with an understanding of children's developmental stages, and build on prior experiences.

In his writings Dewey articulates the role of experience and communication in how individuals construct knowledge. He believed that meaning making occurs through interaction between individuals engaged in purposeful activity. Purposeful activities are those that build on children's concrete experience with the world thus providing a personally meaningful basis for learning, and are socially relevant to participation in society. In "The Psychology of Education" Dewey provides the following example:

> "... light, sound, and heat occur naturally but... the significance attaching to these, the interpretation made of them, depends upon the ways in which the society in which the child lives acts and reacts in reference to them. The bare physical stimulus of light is not the entire reality; the interpretation given it through social activities and thinking confers upon it its wealth of meaning. It is through imitation, suggestion, direct instruction, and even more indirect unconscious tuition, that the child learns to estimate and treat the bare physical stimuli." (p.100)

Dewey's notion of society is crucial to discussing constructivism because he addresses the role communication plays in meaning making. He defines society as "...a number of people held together because they are working along common lines, in a common spirit, and with reference to common aims. The common needs and aims demand a growing interchange of thought..." (Dewey, 1900, p.14).

Garrison (1994), writing about Dewey and his influence on constructivist theory, states that meaning is constructed through social participation and then quotes Dewey; "Meanings do not come into being without language, and language implies two selves involved in a conjoint or shared understanding."(p.722) Prawat (1995), also writing about Dewey's contribution to constructivism, suggests that a "...a triangular relationship exists between individual, community, and world mediated by socially constructed ideas..." (p.14) He goes on to say that for Dewey"...knowing is an act of going between" (p.15). This "going between" is the process where individuals communicate, interact and refine their ideas and experiences with others; it is the place where individuals construct their knowledge.

Vygotsky, a key theorist in understanding the social and cultural aspects of constructivism, suggests that children learn more from an activity or experience when they collaborate with others and that social interaction is key to the learning/construction process (Goodman & Goodman, 1990). Vygotsky identified what he termed the zone of proximal development (ZPD) as a way of articulating how and when constructive processes occur, as a way of identifying a tool (Garrison,1995). Vygotsky defines the ZPD as "...the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers." (Vygotsky, 1978, p.86)

In other words the ZPD is the difference between what a learner can do alone and what he/she can do by collaborating with more experienced others (Litowitz,1993). Another way to understand the zone is through the types of concepts Vygotsky identifies. He suggests there are two types of concepts that learners construct: spontaneous and scientific. Spontaneous concepts are those that individuals construct naturally from everyday experiences, concepts parallel to those described by Piaget. Scientific concepts are those which stem from structured activity, such as classroom instruction, and are culturally agreed upon, formalized, more abstract concepts (Fosnot, 1996). The ZPD is the place where spontaneous concepts are moved into or become scientific concepts through interaction with a more experienced peer or adult.

For Vygotsky development is a learning process driven by social interactions with more knowing, experienced others. Vygotsky's zone places communication and social life at the center of meaning making (Lerman, 1996). Meaning making occurs through the interactions that individuals engage in while in the ZPD. Cobb (1994) states that in Vygotsky's theory, learning is actually a process of enculturation. Children pick up and examine objects which lead them to a beginning understanding of the objects' uses and properties. However it is through modeling, and/or discussion, with an experienced peer or adult that they learn the social and cultural applications for this object. The ZPD is not a one way area. The less experienced person in the zone may reveal or suggest a new or unusual way to treat or apply an object (or concept as children get older) which has potential to become common cultural practice. Thus newer members of the culture are constructing their own understandings through initial experiences, refining and redefining them in the ZPD. At the same time they have the opportunity to influence and change cultural practice because the Zone is not just a cultural transmission zone but one of negotiating meaning, and possibly transformation. (Garrison,1994, Litowitz, 1993)

Constructing knowledge, or making meaning, is an involved and engaging process for all areas of learning. This is a true even for mathematics which has traditionally been viewed as a subject where learning is equivalent to memorizing a series of steps and facts. Davis, Mahar and Noddings (1990) state: "Learning mathematics requires construction, not passive reception, and to know mathematics requires constructive work with mathematical objects in a mathematical community." (p.2). They concisely sum up a constructivist position for mathematics learning. There is tremendous debate raging among theorists about the role of an individual (often labeled radical constructivists and closely tied to the work of Piaget) and the role of the community (so-called social constructivists, most often identified with Dewey and Vygotsky) in developing opportunity for constructing mathematical knowledge. Noddings (1990) has waded through many of these debates and offers a clear summary of agreed upon positions by the majority of theorists applying constructivist theory to mathematics education:

> 1. All knowledge is constructed. Mathematical knowledge is constructed, at least in part, through a process of reflective abstraction.
> 2. There exist cognitive structures that are activated in the process of construction. These structures account for construction; that is, they explain the result of cognitive activity in roughly the way a computer program accounts for the output of a computer.
> 3. Cognitive structures are under continual development. Purposive activity induces transformation of existing structures. The environment presses the organism to adapt.
> 4. Acknowledgment of constructivism as a cognitive position leads to the adoption of methodological constructivism.
>   a. Methodological constructivism in research develops methods of study consonant with the assumption of cognitive constructivism.
>   b. Pedagogical constructivism suggests methods of teaching consonant with cognitive constructivism. (Noddings, 1990, p.10)

The importance of accepting and understanding constructivism in relation to learning in general, and to learning mathematics in particular, is that it implies a vastly different approach to teaching from what is currently used in many classrooms. Baroody and Ginsberg (1990) describe the typical approach to teaching mathematics as a "tell-show-do approach." The teacher tells a class what they need to know to solve a problem, then shows some examples as a model and finally provides problems for the students to practice until they master a fact or procedure. Focus on carrying out procedures is characteristic of the traditional emphasis in mathematics education placed on learning skills rather than concepts (Mills, O'Keefe & Whitin, 1996).

Nolan and Francis (1992) suggest that there are five basic beliefs underlying a traditional mode of the teaching-learning process. These five beliefs include: 1) students learn by accumulating pieces of information and skills; 2) the teacher's role is to transfer knowledge to students; 3) a teacher's main goal is to change student behavior; 4) teaching and learning occur between the teacher and individual students; and 5) thinking and learning skills are applicable to all content areas. In practice these beliefs create a very teacher-centered classroom, and provide little opportunity for constructing mathematical concepts.

The reform movement in mathematics education is based on a *student-centered* approach, which is challenging to the beliefs of many teachers. Battista (1994) suggests that the shift from a traditional behaviorist model to a cognitive model is difficult for teachers because they do not understand how students learn mathematics. In the traditional model teachers focus on sequenced procedures outlined in texts, whereas now they must provide opportunities for students to construct mathematical understanding. Rather than offering strategies, teachers are to provide opportunities and stimulation for their students to construct their own mathematical ideas (Schifter & Simon, 1992).

Moving away from the "tell-show-do" traditional model toward constructivist based models of teaching and learning is a key goal of the Standards. Burns (1994) suggests three broad requirements needed for teachers to make such a shift: valuing and trusting children's ability to make sense of mathematics, acceptance of mathematics instruction based on thinking and reasoning, and genuine curiosity and delight in children's thinking.

Wood (1993) also offers a list of teaching implications based on a constructivist perspective. According to him, students should be engaged in solving problematic situations; children's approaches to solving these should be validated by teachers; teachers should recognize that children's errors are reflective of their current level of understanding and, that learning occurs over time, through conflict and confusion and social interaction. Expanding on the idea of conflict and confusion, Steffe (1990) states that teachers should plan situations where cognitive conflicts arise, causing students to construct new understanding. She suggests that the most effective way to do this is to watch for inconsistencies in student mathematical understanding and use them as a starting point for planning.

Pirie and Kieren (1992) suggest that the teacher's job in teaching mathematics is to create a constructivist climate. They identify four key principles for teachers to effectively create a constructivist climate. The four principles they identify are: understanding that students' mathematical learning progresses at variable rates resulting in different levels of achievement, acceptance that students travel different routes to gain mathematical understanding, awareness that individuals hold different mathematical understandings, and knowledge that understanding is changeable. Once a constructivist climate is created, any number of activities may be appropriate for engaging the students in developing mathematical understandings.

Frye (1989) provides a more concrete list of activities that she recommends implementing, a list which supports and shares elements of Wood's list and could easily be incorporated into a constructivist environment. She says that students need to have collaborative experiences, to use calculators and computers, and to engage in activities that include hypothesizing and testing, problem-posing, experience, and applying mathematics. Kamaii and Lewis (1990) suggest that games and "situations in daily living" are effective activities for fostering construction of mathematical knowledge.

Collectively the above authors provide evidence for the reality that constructivist theory translates into classroom practice. Each author recognizes and articulates ways that students can actively construct their own mathematical knowledge within the context of a classroom. The common threads in their suggestions are: collaboration, solving complex problems that have some relevance to real life, providing a variety of tools for problem solving, and facilitating rather than dominating the learning process.

Weaving these threads into a whole cloth is challenging for teachers who are concerned about covering a curriculum, uneasy about their own mathematical understandings or fearful about classroom management issues. Becoming a facilitator, moving towards a student-centered model of teaching, requires a process of co-construction which many teachers are unfamiliar with themselves.

Cobb, Yackel and Wood (1992) comment on the dilemma teachers face between believing that students actively construct mathematical knowledge and having in mind, or being told, specific mathematics content goals which must be met within certain time frames. In the traditional model mathematical knowledge is viewed as a predetermined body of facts that students must acquire, typically based on their grade level. In the constructivist model mathematical knowledge needs to have purpose and meaning to the individual. Purpose and meaning are developed through participation in a community. As Fosnot (1996) says "We cannot understand an individual's cognitive structure without observing it interacting in a context..." (p.24) Planning for constructivist teaching requires ability to identify needs through observations and flexibility to plan activities that engage students meaningfully in constructing.

Pate, Homestead, and McGinnis (1997) offer support for integrating curriculum based on constructivist teaching principles. They cite Brooks and Brooks (1993) in particular as their source for articulating constructivist principles. The five guiding principles of constructivism offered by Brooks and Brooks include: "Posing problems of emerging relevance to students, Structuring learning around primary concepts: the quest for excellence, Seeking and valuing students' points of view, Adapting curriculum to address students' suppositions, and Assessing student learning in the context of teaching." (p.33) These principles particularly summarize constructivism from the learners' perspective. Pate, Homestead, and McGinnis adopted these statements as a foundation for changing their approach to curriculum design from a teacher/district-centered curriculum to an integrated, student-centered curriculum.

"Integrated curriculum provides experiences for students that are inherently compelling." (Pate, Homestead, & McGinnis, 1997, p.8). Integrating curriculum allowed them to implement the principles outlined by Brooks and Brooks. Integrating literature into the curriculum allows student brains to make their own sense and connection with a concept, provides opportunity for emotional engagement. A story elicits a response, positive or negative, and therefore has the compelling element Pate, Homestead, and McGinnis identify. Teachers have integrated children's literature and math with many 'inherently compelling' themes.

Brain-Compatible Learning

As with constructivism, brain-based, or brain-compatible, learning theory focuses on how individuals make meaning. The key difference between the two theories is that brain-based learning is grounded in the biology of how the brain works and the effect this working has on how we make meaning. Brain-based learning theory weaves together knowledge of how the human brain functions and the following two broad aspects: "(1) designing and orchestrating lifelike, enriching and appropriate experiences for learners and (2) ensuring that students process experience in such a way as to increase the extraction of meaning." (Pearce, Pease, Copa, & Beck, p. 19). Tomlinson and Kalbfleisch (1998) state "each brain needs to make its own meaning of ideas and skills" (p.54). This statement, which comes out of their examination of brain research, is constructivism very simply put. What brain research offers educators is clues based on physiology about more effective ways of creating opportunities for learners to make meaning.

Brain-based learning builds on the idea that the brain is naturally designed to make sense of the world; it is a pattern seeker. Hart (1983) defines the process of learning as ..."... the extraction from confusion of meaningful patterns." (p. 67). He points out that while it makes sense to people to organize and logically present information, the brain does not learn in an organized manner. Each person learns in a variety of ways. This has a profound affect on how teachers plan and organize lessons. As with constructivism students need opportunities to interact and make sense of their world from each other, reflecting on personal experience outside the classroom, and open-ended, meaningful explorations within the classroom.

In order to design brain-compatible instruction we need to understand how the brain works (Hart 1983). Paul MacLean's triune brain theory, developed in the 1950's, is a clearly articulated model for identifying which parts of the human brain respond to certain stimuli and how each part contributes to or controls the learning process (Caine and Caine, 1991, Hart, 1983, Jensen, 1995, Ross & Olsen, 1995). Fogerty (1997) suggests that his model of the brain is simplistic, especially in light of what newer research shows about how the brain works, but is an accessible model to gain insight into brain functioning.

MacLean suggests that the human brain is actually three brains in one; each part has its own function from which we continually downshift and upshift throughout the day (Ross & Olsen, 1995). Each theorist suggests different terms for the three brain parts, but do generally agree on the physiology of which parts collectively form a distinct function and what the functions are. For the purposes of this paper I will use the terms identified by Jensen (1995) because they are representative of others, and I believe more accessible due to the language he selects. He states that the three parts of the human brain are: 1. the lower brain, often called reptilian, which includes the brain stem and cerebellum, 2. the mid-brain, often called the limbic or mammalian brain, which includes the amygdala, hippocampus, hypothalmus, pineal gland, thalmus and nucleus accumbens, and 3. the neomammalian, sometimes called the thinking cap, which includes the cerebrum and neocortex.

Caine & Caine (1991) outline the functions of each section of the brain through a simile of three brothers sharing a house. The eldest brother represents the lower or reptilian brain. This brother is responsible for maintenance, including basic body functions, has no language (although he can sometimes respond to it) and has automatic, nonverbal responses to any perceived threats. This brother is also very resistant to change. The second brother represents the mid-brain; his role in the household is to feel. He monitors emotions, remembers new information, organizes events and maintains balance between the oldest and youngest brothers. All of his functioning is based on the quality and intensity of his feelings. The youngest brother is the largest, and represents the neomammalian brain. This brother is creative, uses language, can analyze and solve complex problems and is able to both anticipate and plan for future events. He is the one who can truly learn if his brothers' needs are met first.

Each brother interacts with the others and they generally work well together. If any threat, physical or emotional, is perceived the older brothers tend to take over. This takeover is what causes the downshifting. (Ross and Olsen, 1995) Caine and Caine (1997) define downshifting as a psychophysiological response that causes a person to respond more out of instinct than reason. Without fear or perceived threat the brain is more capable of operating in complex, thoughtful ways. The situations that are most likely to bring on downshifting are: inadequate or limited time, external reward systems, limited personal connection or meaning, 'one right answer' assignments and projects, and expectations of work are set with little support or background. (Caine and Caine, 1998). They state that recent brain research suggests that to a great extent we operate from and are 'ruled' by the midbrain. They go on to suggest that this information revises the direction of teaching from preventing downshifting to creating an environment that encourages and enables maintenance of upshifting.

Environment is a topic that is frequently identified in studies of brain function and brain- based theory. Interaction with the environment has a physical effect on the brain that can be seen on PET scans and MRIs. The adult human brain is an organ weighing about three pounds. The brain is composed of two types of brain cells; glia which are the majority at ninety percent and neurons which make up the remaining ten percent (Jensen, 1998). The neurons, also called nerve cells, are continually active. Made up of a cell body, dendrites and axons, the neuron acts as an information processor for chemical and electrical signals that enter through our senses. This physiological description is consistent in available research but there is great discussion about other ways of discussing what the brain does or how brain research can inform educational practice.

Bruer (1998a, 1998b) is vocal in his caution about making broad educational decisions based on neuroscience without carefully examining the science behind it. He points out a difference in terminology used by neuroscientists and educators, particularly in relation to environment. Neuroscientists use the term complex when describing the environment as opposed to the term enriched used in educational contexts. Bruer points out that as used by educators, enriched is often laden with value judgements. He offers video games, MTV and shooting pool as examples of activities that are complex but not suggested as part of an "enriched environment" in any brain-based resources. Enriched environment is used by all the brain-based theorists; for the purposes of this paper 'enriched' should be interpreted in the broader sense of complex as used by neuroscientists.

Wolf and Brandt (1998) also question what legitimate connections can be made between new knowledge about from neuroscience research and education. They point out that brain science is a very recent and rapidly evolving field. Of the information currently available they identify four broad findings that are consistently supported by brain research. These four findings include: the brain changes in response to the environment in which it operates, intelligence is not set at birth, there are some periods of time in development which are are more crucial than others, and that emotion has a powerful impact on learning.

Kruse (1998) also offers a collection of statements about cognitive processing based on current brain research. Many of the statements he makes either echo or support those of other theorists cited in this chapter. He is included here to lend further support to the idea that while there are still many questions to answer about how the brain functions and what this information has to offer to educators, there are numerous ideas which are supported and consistently held by the majority of theorists in brain-compatible learning. His ten item list includes the following:

> "1. The brain is a learning organ.
> 2. The brain constantly searches for meaning.
> 3. The brain is a dynamic processor of information.
> 4. We can enhance or inhibit the operation of the brain.
> 5. Learning is a "sociocognitive act" tying social interaction, cognitive processing, and language together in an interactive manner.
> 6. Multi-sensory activities that embed skills and facts into natural experiences appears to enhance the brain's search for meaning.
> 7. A school day in which connectiveness exists between concepts taught enhances the brain's search for meaning.
> 8. The pace of instruction appears to influence the brain's search for meaning,
> 9. Information delivered within the student's context, tied to his or her prior understanding, and moving from concrete to abstract levels of processing appears to enhance the brain's search for meaning.
> 10. To learn (beyond a perceptual level) requires the student to "act on the learning. To act means involvement." (p. 76)

These statements imply that a different approach to the traditional model of teaching and learning is needed to engage the brain. The statements also link directly with the recommendations outlined earlier for constructivist learning.

Caine and Caine (1997) identify twelve principles of learning based on how the brain operates, which support and elaborate on Hart's definition of learning. The principles they outline also overlap with Kruse's summary of brain research. These principles include: the brain is a complex adaptive system, the brain is a social brain, the search for meaning is innate, the search for meaning occurs through patterning, emotions are critical to patterning, every brain simultaneously perceives and creates parts and wholes, learning involves both focused attention and peripheral perception, learning always involves conscious and unconscious processes, we have at least two ways of organizing memory, learning is developmental, complex learning is enhanced by challenge and inhibited by threat, and every brain is uniquely organized.

According to Caine and Caine (1991) brain-based learning consists of capitalizing on students' intrinsic motivation, generating and maintaining relaxed alertness, orchestrating immersion, and encouraging active processing. Each of these aspects is expanded and supported by the creation of the brain-compatible environment, or enriched environment. Ross and Olsen (1995) outline eight components which constitute a brain-compatible classroom environment. These components include: absence of threat, meaningful content, choices, adequate time, enriched environment, collaboration, immediate feedback and mastery. Lloyd (1995) also poses the same eight elements but names one component "trust" instead of "absence of threat." They emphasize that each component is necessary at all times in order to maintain engagement of the neomammalian brain. Absence of threat, or trust, is based on the relationship a teacher establishes with each student and how the classroom community is developed and maintained. Classroom management is a key aspect of this element, as is the development of social skills. Meaningful content is formed around two basic student-oriented questions; “Why do I need to learn this?”, and “How can or will I be able to use it?” A first step in responding to these questions is recognizing and engaging student’s prior experiences. Ross and Olsen suggest that designing curriculum that is creative, useful and has an emotional element both furthers the interaction between student and teacher and enhances development of natural knowledge.

Providing choices is essential because it engages students’ interests, allows students to develop independence, supports the variety of intelligences each prefers and allows the brain to work in its preferred mode of pattern-seeking. Choices should be real, connected to meaningful content and immerse students in experiences. Providing choices relies on students having enough time to investigate and experience content. Enriching the environment is achieved by using as many firsthand sources as possible for learning including access to knowledgeable people and accurate nonfiction print materials. Providing a wealth of supporting resources including books, videos, pictures, and technology, allowing for student movement and physical comfort, keeping the class neat and materials available focused on the current area of study are other components of enriching the environment.

Collaboration refers to teaching and developing the social skills students need in order to work together effectively. Students should work in groups on meaningful projects that are relevant. Processing how work is accomplished is a key component of developing and furthering collaboration. Processing is one aspect of providing immediate feedback both from the teacher and between peers. By acting as a facilitator in the classroom teachers are better able to circulate as students are engaged in collaboration and provide constant and immediate feedback. This component allows teachers to see what is working, who is working and what adjustments might be needed. It also supports the absence of threat so vital to maintaining brain engagement.

Immediate feedback is integral to building trust and collaboration. Students need to hear and see how they are doing. This feedback should come from peers, other adults in the school and local community as well as the classroom teacher. Mastery, although last on the list, is an ongoing event. Strategies employed by teachers using authentic assessment are a good match for helping students reach mastery in a brain-compatible class. Assessment that is authentic is continuous, integral to the curriculum, developmentally appropriate, builds on students' strengths, encourages self reflection and is collaborative (Bridges, 1995). Each of these six components echoes other aspects of the brain-compatible classroom thus making mastery a part of what students do, not an added-on event of proving knowledge or accomplishment.

The brain-compatible components viewed as eight separate items seem an overwhelming task to organize and maintain in place at all times. However, as each one is visited it becomes apparent that one relates to another and directly supports the effectiveness of creating the overall learning environment. At the core of each component is recognition and identification of what is meaningful for students so that they can learn, construct, their knowledge most effectively. These components are present in the classroom and curriculum design approaches outlined above by Frye (1989), Wood (1993) and Pierie and Kieren (1992) for ideal constructivist-mathematics classrooms.

Marshall (1998) interprets the concept of brain-based learning environment in a broader, more community-oriented way. She suggests that a brain-compatible school community havethe following: a curriculum based on questions meaningful to students and learned in a whole way (personalization and coherence), recognition that learning goes on outside of the classroom, learning experiences which are based on relevance to the real world, opportunities for intergenerational learning, students working with adults and peers collaboratively, and learning that is focused on recognizing and solving problems. Her ideas fit well with the community service learning models which many schools are currently engaged in. She also fits better with the neuroscientists' concept of complex environmentas she is applies the ideas of brain compatablity beyond school walls. She recognizes that learning takes place everywhere and constantly.

Caine and Caine (1991) identify two dimensions of meaning; felt meaning and deep meaning. They describe felt meaning as our making connections, having insight and the 'aha' sensation. Deep meaning is what drives us, governs our sense of purpose; it is our source for personal meaning, our passions. When information, felt meaning, and deep meaning come together we have natural knowledge. They believe that expanding natural knowledge is the objective of education. Expanding natural knowledge involves engaging students' prior knowledge and their emotions in order to increase the quantity and quality of connection in the brain. Each of our brains have an infinite capacity to make connections. The key for educators to keep in mind is, learners' overwhelming need for meaningfulness and recognition that learning takes place constantly and everywhere.

Gardner's (1983) theory of multiple intelligences can influence classroom practice and also add to our understanding of how the brain affects learning. His theory, which identifies eight unique intelligences, invites us to question "How are you smart?", rather than "How smart are you?" (Jensen, 1995). The intelligences he has identified include: verbal-linguistic, musical-rhythmic, interpersonal, intrapersonal, bodily-kinesthetic, mathematical-logical, spatial, and naturalist (Checkly, 1997). Viewing intelligence as a collection of strengths, supports and helps planning in a brain-based curriculum. Guild and Chock-Eng (1998) outline six ways that multiple intelligence and brain-based learning theories overlap. They found that both theories are focused on the learner, that teachers make decisions that are appropriate for their students needs, students learn and practice reflection, learning is focused on the whole person, curriculum is meaningful and supports diversity. They suggest that to implement either theory teachers must recognize that these theories continue to be revised and updated. They also make clear that the focus of these theories is facilitating classrooms that support and engage learners in the many different ways learning occurs.

A traditional view of intelligence assumes either you are smart or you are not smart. By starting with the positive assumption that everyone is smart in some way, and then articulating specific areas of intelligence, Gardner provides educators with a tool for planning and self-reflection. Recognizing a variety of intelligences provides teachers with a clear set of areas to design within. Because each of us is stronger in some intelligences than others, planning in ways that incorporate all the intelligences encourages students to gain strength in their preferred intelligence and stretch their skills in those less preferred. It also causes educators to examine their preference and include their less preferred in planning.

Students' prior experiences of the world are a vital foundation for building curriculum. Each student has a schema for the topics explored in school. According to Kaplan, Yamamoto & Ginsberg (1989) for many children the schema for school math is getting the one right answer, without thought. They suggest that educators need to focus on approaches that encourage children to identify and generate patterns. Their suggestion is clearly brain-compatible as it echoes exactly how our brains work most naturally and effectively. Caine and Caine support Kaplan, Yamamoto & Ginsberg when they state that students need to be able to carry out procedures (the narrow, traditional view of mathematics education) *and* understand what they're doing.

In their work at a California school, Caine & Caine (1995) describe the process of a school staff (they included all adults in the building in this process to enhance schoolwide understanding and support) moving from a traditional teaching and learning model to a brain-based learning model. One of the first issues they worked on with staff members was making a shift from viewing learning as memorization of information towards truly meaningful learning. A key to this shift was understanding that the brain seeks patterns naturally and that the brain is a parallel processor; i.e. given the opportunity our brains will naturally strive to make meaning and can do this on many levels at the same time.

As the staff members began to believe in the brain-based model they had to view themselves as learners in the process. This view is quite different from the traditional model where teachers have the knowledge, organize it, present it and finally assess how well the students have learned it. A brain-based classroom is more organic, a place where teaching and learning evolve together based on questions and needs that arise during a course of study. The elements of brain-based learning were essential for the staff to experience and explore directly in order to be able to change their practice. As they engaged in activities and discussions about relaxed alertness, orchestrated immersion and continual processing of experiences, each gained firsthand knowledge of the core elements.

Working with this school staff Caine and Caine (1995) used the elements of a brain-based environment outlined by Ross and Olsen (1995) in order to facilitate change. They allowed three years and spent much of their early work on establishing a nonthreatening environment. The work they did was based on the experiences staff members brought to the workshops which in turn continually enriched their environment. As they worked together to learn about brain-based learning they were in constant collaboration and both giving and receiving feedback. All aspects of brain-based learning were in practice, furthering the connections individuals made amongst each other and the ideas they were learning about. They were able to make brain based learning part of their natural knowledge because they were learning in a brain-compatible manner. As Cobb (1989) suggests, students with their teachers negotiate understanding based on the materials they choose.

Professional Standards

To assist teachers in moving from transmission to constructivism NCTM published Professional Standards for Teaching Mathematics in 1991. Divided into three sections, Standards for Teaching Mathematics, Standards for the Professional Development of Teachers of Mathematics and Standards for the Evaluation of the Teaching of Mathematics, this document provides educators with an outline of pedagogical changes designed to help them implement the Curriculum and Evaluation Standards. The professional standards clearly state that paper-and-pencil drill must cease to be the focus of math education (NCTM, 1991). The vision of teaching outlined in the professional Standards focuses on meaningful mathematical activity and genuine discourse about mathematical ideas. To implement the curriculum Standards effectively teachers need to create a learning environment where risk taking and reflection are encouraged, where students' ideas are respected and mathematical reasoning is fostered. It is recommended that they select actions which have mathematical integrity, engage students and help students to develop their ability to reason and communicate mathematically (Friel, Cooney, Ball, & Lappan, 1990). Heaton (1996), writing about teachers changing their mathematics practice as part of their own professional development, suggests that in a constructivist setting emotions such as frustration, confusion, and puzzlement need to be framed as positive feelings. These emotions are usually related to 'not getting it' in a learning situation; however, they are key to genuine learning. This is a prime example of how brain-compatible learning and constructivism overlap. Creating an environment where problem solving and exploration are safe, supported activities meets the recommendations outlined above for learning and teaching in a manner that is both constructivist and brain-compatible.

Conclusion

The overlap between descriptions of constructivist classrooms and brain-compatible environments provides a clear picture of what people need to learn most effectively. For effective learning to take place teachers need to offer: developmentally appropriate activity, learning in context, meaningful and purposeful exploration, a multimodal approach, opportunities and support for collaboration, and a positive learning environment. At this time the strategy of implementing children's literature and mathematics has been described purely in narrative terms. Teachers and students offer their experiences, many of which appear very positive. Resources continue to be published for designing integrated learning opportunities, demonstrating continued support for using literature to teach math concepts. It's time to examine this strategy against the backdrop of the articulated theories on how people learn. Without some support or direct connection to genuine learning theory integrating math and literature is doomed to be "a great idea" or just the next/last passing educational fad.

CHAPTER III

DESIGN OF THE STUDY

Approach

I designed and analyzed case studies of two classroom teachers to answer the following questions: 1. How does a teacher come to implement integrating children's literature and mathematics as a strategy for designing mathematics instruction?, and 2. Is integrating children's literature and mathematics a teaching strategy that is constructivist and/or brain compatible? I chose a qualitative research methodology rather than a quantitative research methodology because it focuses on descriptive analysis of data collected in a natural setting. I selected a case study model because it is a qualitative research design used particularly for focused examination of some clearly identified event or person or strategy (Bogdan & Biklen, 1992). In this study each of the individual teachers and the specific strategy of integrating children's literature and mathematics were areas of focused examination.

Case study methodology is ideal for in-depth investigation (Feagin, Orum, & Sjorberg, 1991), and Tellis (1997a) states that case study satisfies the "...three tenets of the qualitative method: describing, understanding, and explaining." To construct a case study Yin (1994) outlines six key sources for collecting data. These sources include: documentation, archival records, interviews, direct observation, participant observation and physical artifacts. He comments that each source has strengths and weaknesses; therefore case studies should use as many sources as appropriate to the study designed. Tellis (1997b) states that triangulation in a case study can be achieved by using several sources of data.

Simon and Tzur (1999) offer further support for case study methodology particularly as applied to mathematics teaching. They propose a model of mathematics teacher research which is focused on what the teacher can do, unlike numerous deficit studies published on what teachers do not know or can not do. Their model, named 'accounts of teachers practice' is designed for researchers to examine teachers' current practice and place teaching practice into a theoretical framework. The goal of this type of research is to support teachers in furthering their professional development towards implementing Standards-based practices. My study is designed to look at the practice of two teachers against the theoretical frames of constructivism and brain-compatible learning.

Each case study for this research project focuses on one veteran elementary classroom teacher in the beginning stages of integrating children's literature and mathematics as a teaching strategy. The teachers, Elizabeth and Catherine, were selected because each was focused on changing her mathematics teaching practice; one due to participation in SummerMath, an intensive professional development course, the other due to the leadership of her school district's curriculum coordinator and participation in a variety of professional development venues. I had the opportunity to observe and work with each of these teachers for at least a year before conducting this study. This time gave me an opportunity to establish a comfortable working relationship with each teacher and the opportunity to learn about their particular focus on engaging in professional development for mathematics teaching. It was through discussion that I discovered their interest in integrating literature and math as a next step in expanding their approaches to teaching mathematics.

The data I collected for the case studies includes teacher interviews, teacher journals, documented phone discussions, classroom observations of integrated children's literature and mathematics lessons, and lesson related materials. I conducted interviews with each teacher before the school year began, focusing on their teaching background, how they approach teaching mathematics, why they are choosing to integrate literature and mathematics at this time, and how they plan to integrate the two. I followed the general interview guide approach outlined by Patton (1990). This approach allows for flexibility in the order, wording and timing (for response) of the questions asked in an interview. Each inteview focuses on the same key issues but allows for responsiveness based on the responses of the interviewee.

These interviews were conducted at each teacher's home in late summer about a month before the school year started. The length of the interviews varied based on the teacher's style of responding. Elizabeth answered all my questions in one sitting; Catherine neded two sittings to respond to all the questions. Both teachers were asked the same questions; there were also follow-up questions based on their individual responses. The interviews were taped and transcribed for analysis. Based on information and questions that came out of the interviews I provided some resources to support the planning the teachers were engaged in. In addition to the interviews I asked the teachers to keep a journal of their process of planning and implementation, to document comments and questions about their decisions. There were also several phone conversations both before school, and after the school year began, that I recorded in writing to add to journal entries. I used patterns among the responses to my interview questions for analysis.

Once the school year began my primary focus of exploration broadened from the teacher herself to include the actual lessons taught which integrated children's literature and mathematics. Scheduling observations of the lessons was dictated by the teacher's individual approach to integration, and the timing each felt appropriate to her class. The teachers called me to say when a lesson was to be implemented and I attended as a data collector. I observed lessons any time the teachers called during the first two months of the school year for a total of thirteen observations. I have chosen three representative observations from each classroom to analyze for constructivist, brain-compatible learning theory in action. I selected those lessons that provided the most information for indepth analysis. As I observed it became apparent that the style of implementing this strategy was unique in each classroom. In Elizabeth's class each lesson focused on one particular book. In Catherine's class all the lessons observed were connected to the same book. I analyzed both classes using with the same strategy; my goal is to identify theoretical underpinning for integrating children's literature, not to compare the different styles of teaching.

I analyzed each of the six lessons for the presence of the elements of a brain-compatible classroom as outlined by Ross and Olsen (1995) and Lloyd (1995) and the principles needed for creating a constructivist climate suggested by Pirie and Kieren (1992). I chose these two models as a framework for analysis because they provide ways of making brain-compatible learning and constructivist theory visible in the classroom. I focused on Pirie and Kieren in particular because of the key role the learning environment has in brain-compatible theory. In data gathering I looked at the class response as a whole for analysis, not individual students' responses to the strategy of integrating literature and math.

The figure that follows summarizes the theories I used to analyze the data collected during integrated literature and math lessons.

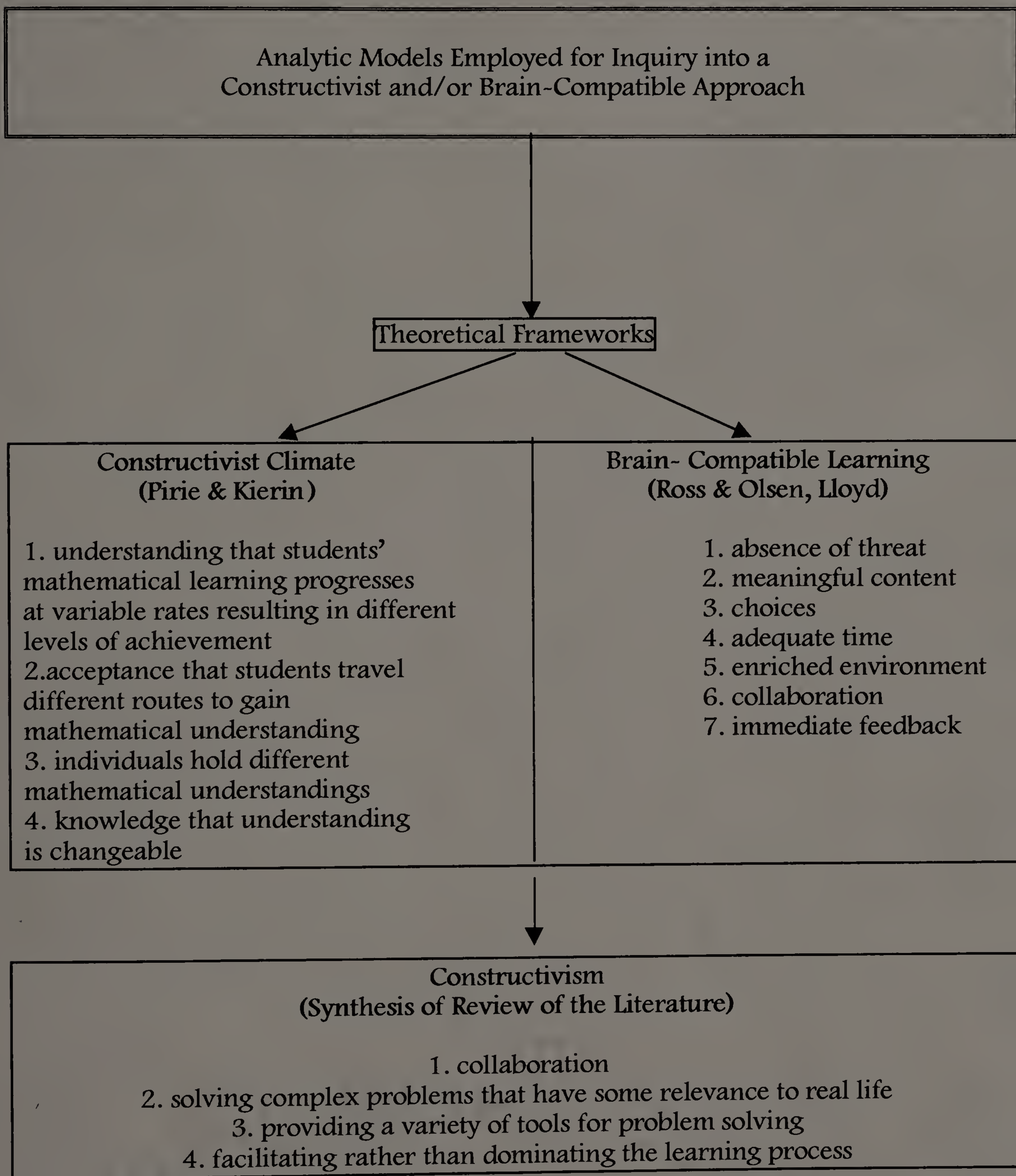

Figure 1. Analytic Models for Inquiry into a Constructivist and/or Brain-Compatible Approach

Delineations

This study is limited by focusing on only two, female, Caucasian individuals. Both participants are veteran teachers and have continued to seek professional development throughout their careers. The communities where these teachers are employed are predominantely Caucasian, middle-class communities, offering limited perspective on this strategy for other populations. Both teachers work at the elementary level, one in third grade, the other in sixth grade; two grades out of the seven elementary levels (K-6) is a small perspective.

Using constructivism and brain-based learning as lenses for analyzing connections between curriculum integration and learning theory offers only one perspective; other theories of learning that may also be connected or supportive of integrating literature and mathematics are not examined here. I have selected one articulation of constructivism (Pirie & Kirien, 1992) and two brain compatible theorists (Ross & Olsen, 1995, Lloyd, 1995) as sources for designing my theoretical analysis. Although there are many other constructivist theorists to choose from for use as filters for analyzing integrated math and literature lessons, Pirie and Kirien's focus on constructivist environment for learning mathematics is specific enough to visualize in the classroom setting. I selected the Ross and Olsen and Lloyd articulations of brain compatible learning because they clearly identify specific elements which I could use for data analysis. The analysis of lessons for brain-based components and constructivist aspects is achieved solely through the data I collected. Another limitation to this study is the small number of lessons analyzed for constructivist and brain-based elements.

As the researcher, my perspectives and beliefs about effective integration will have an effect on the collection and interpretation of the data collected. The decision

I made to focus on the teacher's planning and implementation of integrated lessons is a limit on the data. Students' responses to the lessons are observed from a whole class perspective, thus giving limited information about individual response to integrated lessons. This whole class perspective caused me to make some generalizations about student responses. Student responses are used for determining evidence for presence of some theoretical elements; my interpretations of their responses affects my determination of whether or not they match a theoretical element.

CHAPTER IV

DATA PRESENTATION AND ANALYSIS

Introduction

This chapter presents the data I collected to answer my two research questions: 1. How does a teacher arrive at the decision to implement integrating children's literature and mathematics as a strategy for designing mathematics instruction?, and 2. Is integrating children's literature and mathematics a teaching strategy that is constructivist and/or brain compatible? Data to answer these questions were collected through interviews with both teachers before the school began, journals they maintained, documented phone conversations, and observations of lessons integrating literature and math. The analysis of lessons that were observed to determine if integrating children's literature and mathematics a teaching strategy that is constructivist and brain compatible is also presented here. Elizabeth and Catherine's experiences of becoming teachers, teaching math, and participating in professional development for math teaching are described first. This section is written from the transcripts of interviews with both teachers, and some journal excerpts. Their individual stories are then analyzed for common themes.

The rest of this chapter focuses on the analysis of three integrated math and literature lessons taught by each teacher. I analyzed these six lessons using the four principles needed for creating a constructivist climate presented by Pirie and Kieren (1992) and seven of the eight elements of a brain-compatible classroom as outlined by Ross and Olsen (1995) and Lloyd (1995). Each constructivist principle and each brain-compatible element is explicated with examples from the data collected during observations of the integrated math and literature lessons.

Elizabeth

Becoming a Teacher

Elizabeth chose education because her father told her while she was in college she had to "do something". She tried several majors before settling on education and says it wasn't until student teaching that she really began to enjoy it. She has been teaching in her current third grade position for thirteen and a half years. Before this position she worked in a kindergarten until she had her own children. While raising her children she worked as a Special Education tutor and aide with junior high students. This experience led her to go back to school for reading certification and her Master's.

In reflecting on her own experience with math Elizabeth says, "...I was never good at math...I remember leaving the classroom (in grade school) crying because I couldn't pass the test for addition facts...it was the beginning of hating math...I didn't understand so I learned to memorize, never to think." In contrast she says, "...reading and writing I've always enjoyed... comes more naturally."

Experience With Math

As a teacher, Elizabeth has struggled with teaching math. When she joined her current school system, in the mid-seventies, the math program in place consisted of an independent program with cards and grease pencils. Children worked independently and came to her for help. When they finished a level in the program they erased their responses from the card for someone else to use and went on to the next level. Soon after beginning her tenure in this district, the district bought a math series that she liked because it gave her something to follow. She says she felt she needed the book, and contrasts this to teaching reading and writing. In language arts she found it didn't take long to stop using the basal. Upon reflection she states that reading and writing seem more natural, something she could do on her own. Commenting on math she emphatically states, "… I don't do math on my own!"

Although still not comfortable with the math teaching Elizabeth was gradually feeling more successful at math teaching. She applied the skills learned while a SPED tutor of breaking large concepts down into manageable chunks and used this strategy in her math teaching while relying on a text to follow. Feedback from parents and students was positive; they felt they were really learning math. Gradually Elizabeth became aware that she was doing too much reteaching and that students were unable to make connections for themselves. She realized that the students, "…knew what to parrot back to me… they were memorizing, which was what I had done… I kept thinking what am I doing wrong, why aren't they getting it?" She also states that she was " Beginning to understand that things weren't making as much sense to the kids as they should be." This awareness occurred in the late eighties.

Professional Development in Math

In response to her recognition that the students were struggling more with math than she thought necessary, Elizabeth began attending workshops with titles like "Making Math Stick". She also experienced a teammate change at this time. She and her new teammate attended the SummerMath program at Mt. Holyoke; this training influenced how they planned their math program. SummerMath is an intensive summer program designed to help teachers examine math as both learners and teachers. Elizabeth also expresses a sense that at this time things were "beginning to happen" in math. She saw that articles in *Instructor*, other teacher resources and trainings were strongly focused on process learning and she was beginning to attempt to integrate math into other aspects of the curriculum. She describes a cat unit she taught where the children were asked to gather data and make graphs as an example of beginning integration. The SummerMath training in particular was clearly a turning point in how she approached not only teaching math, but also how she thought about math.

In SummerMath Elizabeth had several ahas. She found herself unsettled by the mathematical knowledge needed to solve the problems presented during the training. From this experience she realized that she had never thought about there being more than one answer to a problem. She describes making a mental connection between the learning in her Master's reading courses about some children who are developmentally ready to learn and learn well in our schooling system and others who need something different from what the system provides. As she says, "I think the beginning (of changing her math teaching) was looking at how people learn..." Something else she realized through this training was that although she had been using manipulatives she had been doing "rote manipulatives". She was providing hands-on opportunities but entirely directing how the experience was organized. She came away aware that the children needed to be given more choices.

During the school year that followed her SummerMath experience Elizabeth made several changes in her math teaching. Teachers who participated in SummerMath at that time were observed several times during the year so they had support and feedback in making curriculum changes. She says that it was the combination of teaming, follow-up support from SummerMath staff and her own desire to change her practice that guided her new direction in math.

One of the first steps she and her teammate took was to begin writing their own problems. She shares an early example of inviting the kids to figure out how to share the coathooks available to their class for hanging jackets and backpacks. The children came up with a variety of solutions and the class chose one of their designs for assigning the coathooks. She says it was chaotic but they just kept going. Although she was comfortable with process writing and teaching reading without the basal as a foundation she found herself asking "Why is this so much harder in math?" She gradually learned that as in reading and writing, listening to the children and guiding their lessons with questions were key strategies in math as well as language arts.

The changes in math were challenging not only for Elizabeth but also for her students. She found that some students who loved math before were now frustrated by what they were being asked to do: to think. Elizabeth still has children practice math facts but her math program is more focused on using problems as a context for the arithmetic. She says, "...we've taken the pressure off right answers". She continually works at improving her skills at writing and identifying challenging problems for her students to solve. She also works with her students to help them see math as a process rather than one right answer. She describes setting up a math lesson now in the same format as a reading or writing lesson where a task or problem is outlined and children collaborate on solutions together.

Changing how children do math in her class affected Elizabeth's math assessments. She says she found herself "listening differently" to the students while they were in action. She has a better understanding of the individual student's skill level because "...I'm listening to them, I'm not the one doing the talking". In creating problems she now knows to leave plenty of work space for students to record their work, their process of thinking, and she has students using math journals. The problem solving focus, working collaboratively and writing about math gives her a richer picture of the students' progress because here are more varied sources for looking at what the children can do.

Integrating Literature and Math

In discussing the changes she made in her math program Elizabeth says she began to look at literature for math lessons because "...math isn't only an isolated skill that you use only at math time during school." She and her students were writing math problem stories to "... couch it (math) in language that made sense and that gave it a context and applied to their world." She viewed reading a story as a natural way of putting math concepts into a context. When asked why she chose to integrate literature when she and the children were already writing their own stories Elizabeth responded, "...broader way of looking at math...they can also bring what they know about story, language and writing to that particular story and math is one part of it". In reflecting on moving in this direction she commented "I think that it's a way of making the math more accessible to some of the children who look at it and say, 'ick', most children love the stories we read...I think the books are a great vehicle for putting math in everyday language...".

Elizabeth read about the idea of integrating math and literature but wasn't sure how to use it. She received money from the school district to buy math resources and decided on Marilyn Burns' Math and Literature (1992) and Read Any Good Math Lately? (Whitin & Wilde, 1992). Elizabeth chose the Burns because she had used several other teaching resources written by her and found them particularly clear and concrete. Although more familiar with Burns, she found the Whitin and Wilde a much better resource. She felt that their book gives more background to the math concepts and offers more book title suggestions. Although she was aware that there were more resources from which to choose, she describes herself as someone who doesn't "like a billion resources". Her preference is to read thoroughly and then add more resources if she needs or wants to.

In deciding how to use literature Elizabeth admits that while she likes things really well integrated she is still wrestling with how to do this. In particular she finds arithmetic a struggle to integrate. She plans to use the children's stories to begin topics or explorations as she sees places where they may fit into the curriculum, or as she becomes aware of specific books that effectively integrate a topic. She is using the resource books she selected, talking with other teachers she knows for book suggestions and working closely with both her school librarian and a town librarian to locate books that are recommended to her, or that she has identified through the resources.

Catherine

Becoming a Teacher

Catherine begins our interview by saying, "I think I always knew I was a teacher." In college she found herself tempted by art but still felt education was the most natural thing for her to do. Reflecting on herself as a student she states, "I was always good in math but never liked it…saw no use for it…had no relevance in my life". She had only one math class in college and one math methods course. She enjoyed the methods course because there was discussion about making the math relevant, which made it personally interesting and fun. Her student teaching practicum was in an urban sixth grade class. She describes watching her cooperating teacher teaching math lessons and dreading having to take on this responsibility. It was the last subject she attempted in her six-week practicum and she left feeling that math was "head stuff". She says, "…it was real, real hard to make myself teach math…remember starting the day with social studies and having a hard time getting out of it because we were having such fun." She comments that she was much more excited about teaching science than math. She learned that it was okay not to know all the answers in science; her approach was to get all the children's books she could find and learn all she could by herself and with the children. She says the idea to use books for teaching science came "because it was what I could understand in science." She comments on how she learned to construct units in her methods course and integrate topics as much as possible, but the message she got from instructors was that this works for everything except math.

Catherine was offered a contract to teach in the school district where she did her student teaching. She taught there for two years. After these two years Catherine stayed home with children and did reading tutoring for a month each summer until returning to the classroom. Catherine returned to teaching, in a different, rural district, as a Chapter I teacher. Her primary responsibility was reading instruction but she also did a little bit of math. She watched what the other teachers were doing in math because she felt she wasn't that good at math and was trying to gather ideas. At this time manipulatives were just starting to be implemented in the younger grades. The following year Catherine took on a classroom teaching position in a sixth grade.

Experience With Math

Catherine team-taught with another teacher; she was responsible for teaching reading and math. She says "I taught a lot of math, and actually that was good because I really learned a lot doing it – realizing how to do things and got better at how to do things." For teaching math Catherine used the district-selected textbook. She followed the text closely believing that "they [text authors] knew a lot more than I did". The focus in the math curriculum was on "what page you were on, not really on what you were teaching".

Professional Development in Math

Ironically the text is a large part of what she identifies as a reason for changes in her math teaching. As she says, "...the books were falling apart...when the books get too old you had to get a new one...it was a textbook curriculum.' With the new texts came support and training. The district hired consultants from a nearby college to involve all the teachers in projects on how students learn math. Grade level meetings became opportunities to "play with new math". In addition to the college consultants the district had a new curriculum coordinator who was also supportive and resourceful about helping teachers change their approach to teaching mathematics.

Catherine acknowledges that the new text and the training and support that accompanied it was the beginning of her recognizing that her own mathematical learning was limited but not worrying about it anymore. She reflects on being scared that she would misinform children about some concepts. From the training she recognized and accepted that the constructive way she approached science was also appropriate for teaching math. The new text offered her different ways of teaching math which she says, "took a couple of years to get". Another change in her practice at this time is how she used the new text. She used this text more flexibly than the former one, selecting chapters that supported project work or were placed in a context that made sense to her. An example she gives is a garden project she does with her class every year. The plants are grown with numerous variables, and measuring is one way of comparing the effects of the variables on the plants. This is a beginning of the school year project, but the measurement chapter is at the end of the text. As she says in relation to the organization, "…these things are thought through; it's just they're someone else's thoughts." She expresses feeling pressure at this time to cover the curriculum partly due to an effort to prepare her students well for seventh grade and partly due to the amount of time she has available for instruction each day. As she says "if you use it (the text) the way it's supposed to your time is taken up" The struggle she identifies, and begins to question, is how to address all the concepts outlined in the text and do integrated, project based learning.

Several other factors were influential in Catherine's changes in teaching math. She credits continuing professional development, both within the district under the leadership and commitment of her curriculum coordinator and participation in outside venues. Catherine attended many workshops and participated in an ongoing, long-term project sponsored jointly by several colleges. She credits the leaders of this project with modeling and supporting how to do project based learning in a way that included and integrated math. She also cites working with student teachers as key sources for refining her practice. She says she "…always asked practice teachers to do math…took notes from them". What she learned from student teachers was a variety of lesson ideas and strategies for integrating math into the curriculum. She also learned math games from them. She says, "I'm not a game person". But the student teachers often brought in or made games for the students to practice or support learning math concepts. What she discovered through this experience was that there were some games she could engage in and that games made the math more real for her students. She also talked with colleagues about what she was doing and thinking, finding these conversations a source of inspiration and motivation.

Integrating Literature and Math

She comments about professional development and the changing 'lingo' she experienced when returning to teaching. She describes her experience going to workshops and half way through realizing, "tsk, I do this, I just didn't realize this was what it was…" This lingo gap is evident when discussing how she came to integrate literature and math. She shares how she used Alice in Wonderland with her class the previous year. She says "I didn't choose Alice because of the math. I chose it because I was curious, interested in words…of course we did all sorts of measuring…it just came naturally, it was an obvious thing to do." Thinking more broadly about how she discusses literature with the kids she notes "…so what I think about math and literature is if something mathematical came up in a story I probably talked about it [in the same way] as anything else…I didn't think oh that's math let's do this – it's not like we are integrating, it's learning… it's not like it's purposeful and planned". In her journal she comments on looking through the NCTM (standards) book and thinking about our conversation and realizes "Of course I had used math with literature before." These comments suggest that she's been integrating in an intuitive way all along.

In deciding to select a math concept as the focus for a unit of study Catherine acknowledges, "I've been moving toward being freer in math teaching, but it's not something I can do quickly (has been in process for about five years) …the idea of teaching, exploring and then doing the math as it comes along is exciting and it's risky and it's exactly the opposite of everything we were taught to do-we were taught to start here and end up over here- in a very linear pattern, and then to try to make real life connections as you can along the way." She chose "Time" as a theme to integrate her curriculum for the first part of the year. This theme came out of a personal experience where a friend was leaving from Belgium and would be crossing the International Dateline. Her daughter asked how long would the friend be in the air; this question proved to be a challenge for her and has stuck with her. She focused on A Wrinkle in Time by Madeleine L'Engle and The Phantom Tollbooth by Norton Juster as books that have "Time" as a theme to begin the year with.

She settled on using The Phantom Tollbooth to begin the school year because of the math and language possibilities. Her approach after the first read-through of Phantom was to reread it and underline all the math concepts that jumped out at her. She then went through the district's sixth grade curriculum guide to focus on key concepts, which she then turned into goals. In addition to this she webbed out the way that she would integrate "Time" into other content areas. She was continually reading books and resources on time to screen and think about more ways of bringing the "Time" concept fully into the class. She also worked collaboratively with her student teacher giving him opportunities to participate in designing activities that support and further the integration of the "Time" theme.

Her journal reflects an abundance of ideas and possibilities and connections to this theme. She comments while in the process of designing the "Time" unit that "this is very exciting and it's rewarding because of having to try to fit math in something before and I don't have to worry about it and I'm realizing how beautifully everything fits in so that's a very big change." She continues to say "...to be able to take a unit from a different place is really fun."

Themes in Elizabeth and Catherine's Movement Towards Integrating Children's Literature and Mathematics

Elizabeth and Catherine's experiences, both as learners and teachers, share many aspects in common that led them eventually to integrate children's literature and mathematics as a teaching strategy. They both comment on their feeling towards math when they were elementary-aged students themselves; “unable” and “irrelevant” most succinctly describes their feelings towards the subject. Each viewed teaching math as a challenge, one they met by following a text or other prescribed approach. Math was a topic that they had difficulty seeing as connected to other parts of the curriculum; a point of view that was revised through professional development.

I think it is significant that both Elizabeth and Catherine identify ongoing support as key to changing their math teaching practice. Although the source of support is unique to each teacher (SummerMath staff for Elizabeth and school district leadership for Catherine), they make it clear in their interviews that integrating math into the curriculum, and making math learning more meaningful, in general came about due to participation in professional development. Another aspect of the professional development that each of them articulated as significant to their change is learning, or relearning math concepts themselves. Because they were placed in a student role each of them came to realizations about mathematics concepts and different ways of teaching math. Elizabeth realized the power of putting math concepts in context, asking questions and listening to students’ whole response, not just their answer. Catherine realized that it is okay to learn with the students and that math can happen, safely, in places other than the textbook.

Deciding to integrate literature and math is a decision that evolved out of changing their math teaching practice. Neither Elizabeth nor Catherine just picked this strategy out and made a snap decision to try it out. Both teachers were engaged in curriculum integration as a way of teaching, before integrating literature and math specifically. And they were both actively engaged in professional development for changing their math teaching. Each teacher expresses that purposefully integrating literature and math was a natural next step for her math program.

One aspect of what makes integrating literature and math natural is that using literature puts math learning into a context. Another aspect that seems to make this decision a natural next step is that both teachers express their comfort level with the language arts. Each of them enjoys reading and felt more comfortable right away with teaching reading and language arts than with the math.

It is remarkable that each identifies a unique way of implementing the same strategy. It is clear that this is a strategy that is implemented with thought and planning. Neither of these teachers picked a children's book and decided to teach a math lesson from it on a whim. Each one of them came to the use of literature as part of a process of learning and reflection on their own mathematics understanding, and their math teaching.

General Description of Classrooms and Lessons Observed Integrating Children's Literature and Mathematics

Elizabeth

Elizabeth's third grade classroom is engaged in a thematic study of bears. It is the third week of school and there are bears (made by the children) hanging from the ceiling, bear poems on the walls, bear posters, a bear tree, bear riddles and the bookcase is stocked with bear books. The class is set up with six tables with chairs where the children do their work. There is a rug on the floor where the class gathers for meetings and discussions. Hanging on the wall near the meeting area is a large chalkboard, a monthly calendar and a job list. The calendar has many details on it beyond showing patterns. The chalkboard has the daily schedule written up in children's handwriting. Elizabeth has a desk that faces out toward the class, a half round table is pushed against the front of it. I never see Elizabeth sit at this desk for any of the classroom observations for the study. At the perimeters of the room are shelves that are open and well supplied with writing and drawing materials, manipulatives, and books.

The first integrated math and literature lesson Elizabeth teaches is based on The Half Birthday Party by Charlotte Pomerantz. She chose this lesson because she discovered that many of the children are unable to identify what month comes before September. This lesson focused on the calendar and the concept of halves, both of which she felt were appropriate and needed topics for this class. In conversation before teaching the lesson she also commented on thinking that using the book would be a fun way to introduce the children to a follow-up activity of finding their own half birthdays. She expressed some concern about how the children would respond to the story because it is an easy reader and is a regular size (she prefers to use big books for whole class lessons). She again cited the Marilyn Burns book and Have You Read Any Good Math Lately? as resources for selecting books.

The second lesson that Elizabeth taught integrating literature and math was based on Two Ways to Count to Ten as retold by Ruby Dee. In her journal Elizabeth writes that she planned this lesson as a beginning of looking at patterns for multiplication. The story is a Liberian folktale that focuses on an animal king looking for a successor. The task he sets for the animals is to throw a spear into the air and count to ten before it reaches the ground. After reading the book aloud there was discussion about how the smallest sometimes wins because of cleverness and thinking out a solution, as well as, the variety of ways to count to ten. In the follow-up activity the ten was expanded to one hundred. Students worked on hundreds charts to show a variety of ways of counting to one hundred, and the patterns their counting made.

In the third lesson Elizabeth focused on A Day With No Math by Marilyn Kaye. She chose this book as inspiration for a homework assignment where the students designed questions to interview their parents about how they use math in their lives. This lesson engaged the students in impressive discussion about what is math and how deeply math is entwined in their daily lives.

Catherine

Catherine's sixth grade classroom has been actively engaged in a study of time during the first three weeks of school. One wall-length bulletin board is labeled "It's About Time". This board is completely covered with time related visuals. The board has a poster of Einstein on one edge, a star picture on the other, a list of questions (What is geologic time?, How long does it take for starlight to reach us?, Do all people measure time the same way?, How long have there been calendars?...), individual timelines students made of their summer activities and posters of individual time webs the students did in small groups. Another bulletin board is labeled "When did your ancestors come here?". This board is about half the wall and has a world map up at the center of it on one side labeled "Where Were They From?", surrounded by handwritten messages from the students describing where their ancestors came from.

The other side of the board is labeled "Some Known Dates of our Ancestor's Immigration" with a timeline showing dates of student's ancestors arrival. The timeline is labeled by century, beginning with the seventeenth century. The classroom has a chalkboard at the front of the classroom. Students sit at desks which are arranged in clusters of fours. At the back of the room there is a table covered with time books and a variety of projects showing students' interpretation of some of the puns written into The Phantom Tollbooth. Near this table is Catherine's desk (she never sits behind it while I observe). The room is equipped with a sink and cubbies for students to store their belongings. At the front of the room is a chalkboard, attached to one side of the board is a long piece of chart paper labeled, "To Do". There are eight items listed starting with "study Big Bang" and ending with "When people used sundials what happened at night, when it was cloudy?"

All three of the lessons I observed and analyzed for this study in Catherine's class focused on The Phantom Tollbooth. The first was about their work on the concept of time, the second about misconceptions the students held about averages and the third focused on a continuation of averages. Averaging appears in The Phantom Tollbooth. In the story Milo, the main character, encounters a boy who is about half visible. Milo wonders what the rest of his family is like. The Boy responds "Oh, we're just the average family, mother, father and 2.58 children-and, as I explained, I'm the .58." Catherine used this part of the book to engage the students in exploration about averages and averaging. It was very difficult for the students to grasp and apply. In her journal she writes, "The averaging is not going amazingly well if articulating the meaning of averages is the assessment tool.- I am not discouraged by this. I just think it proves the point of constructivism-that the kids (and adults) don't change or learn new things easily. I think doing the same thing many times over may help. So this week we'll work on the averages some more."

In addition to guiding her students' literal comprehension of the book, her students needed to understand averaging to use in their ongoing garden project. Catherine and her students created a garden for the science part of the time unit. This is a project she does with her students every year and she wondered how to connect it to her broader theme of time. As she thought about this she realized that time is an essential element of growing a garden. The garden is a living science experiment; treating the plants with different exposures to light, and different nutrients provides students with real data to collect. It was in recording the data that she discovered a direct link to reading The Phantom Tollbooth. The students measured the plants daily to record their growth; to get as accurate a measurement as possible the students took several measurements and then had to average them. When questions arose from the reading about what an average is, Catherine discovered that her students had been doing the computation of averaging for the garden but did not conceptually understand averaging. With the garden project already underway Catherine had two contexts for helping her students learn about averages; The Phantom Tollbooth and the garden.

Analysis of Lessons Integrating Children's Literature and Mathematics for Evidence of Constructivist Theory

To analyze the lessons taught by Elizabeth and Catherine for evidence of constructivist theory I chose Pirie and Kieren's (1992) requirements for creating a constructivist climate as a framework for focusing the analysis. I chose this particular scaffolding because of the key role environment plays in brain-compatible learning. It is my intention to look for ways that integrating literature and math are theoretically grounded in both constructivism and brain-compatible learning. Pirie and Kieren articulate four key principles for teachers to accept and incorporate into their planning in order to create a constructivist climate. The four principles include: understanding that students' mathematical learning progresses at variable rates resulting in different levels of achievement, acceptance that students travel different routes to gain mathematical understanding, awareness that individuals hold different mathematical understandings, and knowledge that understanding is changeable.

To analyze the data I collected from the classroom observations for constructivist principles I created an organizer to sort the data (see appendix for a sample). I listed each of the constructivist principles and also left open space for comments or ideas that did not neatly fit into one principle. Using the descriptions of each principle as described by Pirie and Kieren as a filter, I read and reread the observation notes from each lesson to categorize aspects of each lesson according to the four principles. After completing a chart for each lesson by recording examples and details from my field notes of the observed lessons, I examined each principle for patterns or themes amongst the lessons. What follows is the evidence I found in the lessons demonstrating that each of the four constructivist principles was present in the integrated literature and math lessons taught by both teachers.

Elizabeth and Catherine demonstrated their understanding that students' mathematical learning progresses at variable rates, resulting in different levels of achievement in a variety of ways. Both teachers accepted work from the students based on what they were able to do in response to the specific concept of the lesson. What each was adept at doing was looking at student work to see if a pattern of misconception was individual or held by many in the class. In Elizabeth's class she discovered that although most children could talk about and identify their half birthdays, their conceptual understanding of 'half' as a fraction was very shaky. This led to other lessons on fractions to support student learning of fractions (not with literature.) She did several lessons involving manipulatives, and paper/pencil activities.

In Catherine's class the averaging concept was a similar situation. When she asked students what they thought it meant for an average family to have '2.58 children' some students responded that the family had a child with missing limbs; others were unable to respond. She followed up on these responses and discovered that not only in relation to The Phantom Tollbooth but also in the context of their garden project (see p. 69) her students could not consistently articulate or compute averages. She too followed up with explorations on averaging involving manipulatives and practice calculations.

Another way in which both teachers showed acceptance of different rates of progress was the way in which students were questioned about what they knew, and the openness with which all students' responses were accepted. An example of this from Elizabeth's class was her acceptance of students' numerous approaches to trying to identify different ways of counting based on the reading of Two Ways to Count to Ten. She expected that the students would be able to stay with the connection of looking for ways to count to a particular number. Some children could; others just engaged in a pattern making approach. She allowed students to work at their level of understanding and raise questions where they needed to. In particular for this lesson students wondered if '1' always had to be a starting point for counting, which led to a great discussion about counting. This lesson also overlapped with the next principle, acceptance that students travel different routes to gain mathematical understanding.

Both teachers designed lessons in such a way that students were allowed and encouraged to use both a variety of materials and each other as sources for coming up with answers or solutions to the activities that followed the literature. In all the lessons there were choices for the students to make about how they worked out a problem, where they worked it out in the classroom, and whether they worked alone or together. In most cases choosing to work with someone else was a structured choice; the students were assigned a partner, either by virtue of seating arrangement or random pairings.

To further support and demonstrate their acceptance of the variety of ways to learn the math, both teachers encouraged students to share their strategies and solutions with the class. This processing piece of the lessons was supportive and often inspiring for other students who heard about ways of solving or understanding a concept they had not personally thought of.

The third principle, awareness that individuals hold different mathematical understandings, was most evident in the open ended design of the lessons observed and the frequency of giving students feedback while they were engaged in an a lesson. In each case a task was identified to accomplish but there were numerous ways to approach and participate in the lesson. By circulating constantly while students were at work both teachers were able to provide more or less support where it was needed based on individual needs. Their active role in the class also helped to avoid students with misconceptions or misinformation from leading their partners into faulty thinking or solving.

Knowledge that understanding is changeable, the fourth principle, looked the same in some ways and different in others between the two classes. Both teachers designed their lessons with the ideas that students could or would connect with story in some way and further develop their mathematical understanding based on the concept[s] in the book. There was an affirmative assumption on both their parts that their students would learn something from the lessons. In Elizabeth's class her response at the close of the A Day With No Math lesson was "I didn't think of all these ideas!" which showed her students that the teacher too can learn.

In Catherine's class, because all three lessons were inspired by one book, there was observable continuity to the lessons and a more in-depth approach to a developing conceptual understanding. In addition, Catherine's approach to integrating themes that came out of The Phantom Tollbooth allowed her to encourage and foster concept development in a variety of contexts. I saw two lessons on averaging, both inspired by The Phantom Tollbooth. In these two lessons I observed three different aspects of the students learning about averages. They defined averages to support comprehension of the story, they practiced the computation involved in averaging and they used averages to record data from their garden project. Learning about averages came directly out of reading The Phantom Tollbooth and was addressed with the students in several contexts. Without the literature as a foundation these lessons would not have been integrated.

Because Elizabeth's approach was to choose a succession of books, each designed to address a specific concept, and I observed only those lessons involving literature, I had fewer opportunities for observation and conclusions about her constructivist practice on the whole. For example, after The Half Birthday Party lesson Elizabeth became aware that the students' understanding of fractions needed a lot more support and development. Although she talked about ways of following up on this concept in the classroom, I did not observe these lessons because they did not involve literature. This lesson was intended to provide an opportunity to practice the order of the months; I have no data to draw a conclusion about how or if this objective was met for this story. The lesson I observed and analyzed did exhibit each of Pirie and Kieren's principles, and Elizabeth explained that this was but one lesson in an ongoing unit.

The second lesson I observed and later analyzed focused on Two Ways to Count to Ten. Elizabeth wrote in her journal that this story and follow-up activity was intended as an introduction for working on multiplication. Again the lesson I observed was integrated and had examples for each of Pirie and Kieren's four principles but I have no sense of the students' ability to connect what they did with the long term goal of developing multiplication skills. Elizabeth's third lesson designed on A Day With No Math was more self contained. The focus on this lesson was to engage children in activity to see all the real life places math has in their lives. Through their class discussion and collaboration with each other to design questions for their parents on this topic I could hear and see that the objective of this lesson was met.

Analysis of Lessons Integrating Children's Literature and Mathematics for Evidence of Brain-Compatible Theory

In analyzing the lessons taught by each teacher I used seven (absence of threat, meaningful content, choices, adequate time, enriched environment, collaboration, immediate feedback) of the eight brain-compatible elements outlined by Ross and Olsen (1995) and Lloyd (1995). I am excluding mastery, the eighth element, because I observed only some of the lessons in the entire unit or study. I believe it would be inaccurate to make a determination about mastery in relation to the single lessons observed. I did gather anecdotal data from the teachers about their assessment practices in general and both are actively engaged in authentic practices as outlined earlier by Bridges (1995). Assessment is integral to their curriculum and evident in the lessons I observed. Attention to assessment is also articulated in the teacher's journal entries as they consider how much time to devote to a concept. This element is also somewhat reflected in the immediate feedback given to students during lessons and where lessons begin, reflecting understanding of student needs based on assessing appropriate next steps for learning.

To analyze the data from the classroom observations for brain compatible elements, I created an organizer to sort the data (see appendix for sample). I listed the brain compatible elements and also left open space for comments or ideas that did not match any of the elements in particular. Using the descriptions of each brain compatible element [outlined in Chapter two] as a filter, I read and reread the observation notes from each lesson to categorize aspects of each lesson according to the brain compatible elements. I filled out the organizer by recording details from my field notes which matched a particular element. After completing an organizer for each lesson, I examined the recorded observation details of each element for patterns or themes amongst the lessons. What follows is the evidence I found in the lessons demonstrating that each of the seven brain compatible elements was present in the integrated literature and math lessons taught by both teachers.

<u>Absence of Threat</u>

Absence of threat (or 'trust', these terms are used interchangeably in this study) was evident in both classrooms. Elizabeth and Catherine were clear in our conversations about wanting the first couple of weeks of school to be focused on class community building. I was not invited to observe in either class until each teacher had an opportunity to work with her class on becoming a working community. When I did observe, what I saw were teacher actions and student responses that demonstrated absence of threat in the classrooms. Both teachers set up each observed lesson in such a way that students knew what the focus of the lesson was. Directions, titles, and key words were written on the board to help students focus. The teacher consistently referred to the board so that students could be in charge of refocusing. The facial expressions of the teachers were open, lots of smiling and making eye contact with the class both while reading the story or directing the lesson activity.

Another aspect I found key to maintaining the absence of threat was both teachers' active engagement with the students during the activities. No student had to wait long to get a question answered or to be challenged to push on further. By circulating frequently among the students as they worked anxiety levels were kept low. What was also clear was that all student questions were responded to with supportive answers or thought-provoking questions. There was no judgment on the content or quality of a question raised by a student. If a student response was inaccurate or unexpected, both teachers were skilled at rephrasing the response, posing another question to redirect or suggesting that the student confer with a peer about the response. Students showed their responsiveness by maintaining eye contact while the teacher was talking, readily approaching a teacher for support or confirmation, asking peers for support or confirmation, actively participating in discussion and smiling.

Meaningful Content

Meaningful content looked different in the two classrooms. In Elizabeth's class each book was introduced with some question or connection to engage the students' interest. For The Half Birthday Party the children in this class were excited about their own birthday and curious about sharing or finding out when their half birthday was. The second lesson on Two Ways to Count to Ten was familiar to some children so they were excited to hear it read aloud. Those who were hearing the story for the first time were excited because their neighbors were excited. At the end of the story the students were invited to retell the story, to describe the characters, and share ways of counting they could think of. Making the story itself an activity was effective for getting the students to engage with the content of the story and generated interest and excitement about the follow-up activity. A Day With No Math immediately captured the students' interest. They quickly started listing things they could not do without math; play Connect Four was one example. There was an obvious link to seeing math in their daily lives and how math is vital. They were inspired by the assignment to design questions to ask their parents about their use of math; several children asked to stay in at recess to continue working on their questions. The activity served as a link between home and school which furthered the meaning of the content of this lesson. Students were tickled to think about the responses from home.

In Catherine's class meaningful content had a more organic origin. The lessons I observed were all integrated around the overall theme of time, with The Phantom Tollbooth acting as one source of inspiration for lessons. The students were working on creating their own personal history timelines and exploring the concept of averages. The timelines were clearly engaging and meaningful as they were unique to each student. The averages lessons were initiated by questions raised by the students, and developed a skill needed to effectively record the growth of their garden experiments. The immersion in the theme as an ongoing focus (evident in the lessons and the visual decoration of the room) allowed for a continuity and connection from one lesson to the next.

Making Choices

There were similarities between the two classes in making choices. In all the lessons I observed for analysis students could make choices about the materials (manipulatives, writing utensils, calculator) they used to complete an activity, and they could select where they did their work so long as they were productive. Beyond this choices were fairly limited. Students were expected to complete the task set out for them and the task had clear parameters (find your half birthday, create a timeline). I wonder if this is a function of the age groups of these two classes and the time of year. In Catherine's class there were other more choice-oriented activities, for example design a time keeper of some sort, that were more open ended.

Adequate Time

Adequate time was approached differently based on the approach to integration. In Elizabeth's class, although math was typically a forty-five minute time block in her school schedule, she gave the math and literature lessons a much larger block of time. She was clear in each lesson to let children know when and how they would have more time to work on an activity if they ran out of time on the day the lesson initially began. In Catherine's class, time was both the focus of the study and an issue to grapple with. She was responsive to her students' needs and interests as they arose through their reading The Phantom Tollbooth. She raises concern in her journal about spending too much time on some aspects of this exploration but feels strongly that they must stay with a concept until the students demonstrate understanding.

Enriched Environment

Both classrooms shared a richness and accessibility of materials in the classroom as one form of evidence of an enriched environment. They were also in close proximity to excellent school libraries and full aesthetic arts programs to support learning. Children's work was on display in both classrooms. What was different in the two observed environments was the connection between the environment and the lessons I observed. Elizabeth's class was a welcoming and well supplied classroom but the integrated math and literature activities were not readily evident in the classroom unless the students were working in them. In Catherine's class the theme of time was represented everywhere I looked, and numerous projects that came from reading The Phantom Tollbooth were on display (a long list recording puns and plays on words the students found as they read the book, attempts at making a dodecahedron out of paper). She also extended her classroom environment to the outdoors with the garden project. Their learning took place in many venues.

Collaboration

Collaboration was evident in both classrooms in two forms. Both teachers fostered student to student collaboration and student to teacher collaboration. Children were encouraged to work together on activities and projects. The teachers also encouraged the students to use each other as resources even if they were not working directly together. Both teachers were open to children's input into the lesson.

Immediate Feedback

Immediate feedback is a way of teaching for both of these teachers; it's part of their daily conversation. Already highlighted above in "creating trust" these teachers are actively engaged with their students. Reading the story aloud for each lesson is an interactive process, as is discussion before and after reading. Within this dialog is feedback on accuracy of predictions and support for creative explanations.

Circulating while students did their work, I overheard many supportive comments and guiding questions raised. Feedback was also done in writing; both teachers wrote notes to students on their work.

Analysis of Lessons Integrating Children's Literature and Mathematics for Evidence of Constructivist and Brain-Compatible Theory

In the process of analyzing the lessons to complete the charts I found three elements that were consistently present in all six lessons which did not fit into any one of the constructivist principles as described by Pirie and Kieren. The recurring elements I found include: designing lessons based on students' needs or interests, selecting and offering materials to facilitate or encourage meaningful learning, and beginning a lesson in an engaging way. Each element was woven throughout the observed lessons. I believe that these elements further support confirming that each of the lessons is constructivist in a broader sense than the principles Pirie and Kieren outlined. Each of the three identified elements are grounded in constructivist theory because each one is an example of at least one of the common threads of constructivist practice identified in the review of the literature. These common threads are collaboration, solving complex problems that have some relevance to real life, providing a variety of tools for problem solving, and facilitating rather than dominating the learning process.

Both Elizabeth and Catherine were able to identify why they chose a specific lesson and how it was appropriate based on either observation or assessment of the children's needs or interests. Catherine did this by continuing to explore averages when she saw students' confusion. Her intention was to do one activity and move on; her recognition of their need for more time on this concept resulted in the design of a student-centered lesson. Designing learning from a student-based perspective is necessary for meaning-making, a key tenet of constructivist theory. It is also an example of two of the common threads of constructivism: collaboration, and facilitating the learning process. Each teacher collaborated with her students by designing lessons based on questions raised by the students or evidence of some confusion on their part. They facilitated learning by designing new lessons that met students' needs, not teacher or district agendas.

The second element is supportive of planning from students' needs. Both teachers consistently designed lessons which allowed and encouraged students to use materials to accomplish the activities that went with each lesson. Their ability to select a wide and varied collection of materials is key to the success of the lessons they taught. It demonstrated a repertoire that both teachers had which enabled them to fully support the four principles with their students. This element is an example of providing a variety of tools for problem solving.

One example of the importance of having and using a repertoire of materials to choose from was the follow-up activity Elizabeth designed for Two Ways to Count to Ten. She gave the students hundreds charts to begin working on finding number patterns. When children had questions she was able to encourage them to use manipulatives to better see the patterns, and directed them to specific manipulatives that enabled some of the children to see patterns more clearly. Without her knowledge of manipulatives, several of Elizabeth's students would have filled in the chart by rote, but would not have been able to construct and see the patterns for themselves.

The third element I noticed was that all six lessons observed began with an introduction telling children what the focus of the lesson was. This strategy is a concrete example of facilitating the learning process. In Elizabeth's class this was in the form of a mini preview of the book, asking if anyone had read the selected book before reading it aloud and sharing why the book was selected. In Catherine's class, because the book was the same for all lessons, the introduction was a brief discussion of the last reading and a focusing question or comment. This previewing or introducing the lesson is effective teaching practice; it got the children's attention and gave them an opportunity to participate actively from the beginning. Without student participation and interest there is no opportunity for constructivism to happen. I think it is significant that both teachers made this particular strategy a consistent component of the lessons they taught. An engaging and integrated beginning to the lesson set the stage for a constructivist experience.

As stated earlier, I found evidence of brain compatible and constructivist elements in all of the six observed lessons. There are several areas of overlap between constructivist and brain compatible theories of learning. The overlap between descriptions of constructivist classrooms and brain-compatible classrooms gives a clear picture of what it is that people need in order to learn most effectively. For effective learning to take place teachers need to offer: developmentally appropriate activity, learning in context, meaningful and purposeful exploration, a multimodal approach, support for collaboration and a positive learning environment. In this study both teachers created effective learning opportunities by using children's literature as the foundation for planning and implementing their lessons.

Summary

In order to answer my first research question, "How does a teacher arrive at the decision to implement integrating children's literature and mathematics as a strategy for designing mathematics instruction?", I interviewed two teachers about their experiences teaching math, engaging in professional development about math and how they came to choose integrating children's literature and mathematics in particular. By transcribing the tapes of these interviews and analyzing their responses for answers to my questions, I was able to describe their development as teachers and how each one came to integrate children's literature and mathematics. After describing each teacher's movement individually toward integrating children's literature and mathematics, I looked at both of their experiences to see if there were any themes held in common between the teachers.

To answer my second research question, "Is integrating children's literature and mathematics a teaching strategy that is constructivist and/or brain compatible?", I selected constructivist principles articulated by Pirie and Kieran, and the brain compatible elements outlined by both Ross and Olsen and Lloyd as a basis for analyzing the integrated children's literature and mathematics lessons taught by Elizabeth and Catherine. I chose the first three lessons each teacher taught during the school year for analysis. To analyze the lessons I created a chart of each principle or element articulated by the theoretical framework I had chosen. I completed a chart for each of the six observed lessons, based on my observations. The charts were filled out using details from observation notes taken while each lesson was taught. Each principle or element was then separately analyzed for themes or patterns among the lessons. This process allowed me to see if, based on the lessons observed for this study, integrating children's literature and mathematics is a strategy that is constructivist and/or brain compatible.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

Conclusions

How does a teacher arrive at the decision to implement integrating children's literature and mathematics as a strategy for designing mathematics instruction? Elizabeth and Catherine, the two teachers who participated in this study, each came to this decision through participation in professional development in mathematics teaching. Both teachers began their teaching careers with a lack of enthusiasm and confidence for teaching math. Professional development, sought outside her school by Elizabeth and guided by the school district for Catherine was instrumental in changing their teaching practice. As part of their professional development both teachers identified ongoing support in the classroom as key to making substantive changes in how they approached math teaching. Having colleagues to discuss and inspire different ways of teaching encouraged them to keep changing their approach to math lessons. Another aspect of the teachers' movement to integrate children's literature and math was a readiness to treat math like they did other subjects instead of keeping it separate.

My second question, "Is integrating children's literature and mathematics a teaching strategy that is constructivist and/or brain compatible?" is affirmatively answered by the data presented. In all six integrated literature and math lessons I found the four principles needed for creating a constructivist climate suggested by Pirie and Kieren (1992) and seven of the eight elements of a brain-compatible classroom as outlined by Ross and Olsen (1995) and Lloyd (1995). The four constructivist principles include: understanding that students' mathematical learning progresses at variable rates resulting in different levels of achievement, acceptance that students travel different routes to gain mathematical understanding, awareness that individuals hold different mathematical understandings, and knowledge that understanding is changeable. The seven brain-compatible elements are absence of threat, meaningful content, choices, adequate time, enriched environment, collaboration, and immediate feedback.

Analysis of the six integrated literature and math lessons also revealed evidence of constructivist teaching practice broader than the four principles put forth by Pirie and Kieren. Collaboration, solving complex problems that have some relevance to real life, providing a variety of tools for problem solving, and facilitating rather than dominating the learning process are the four common themes I identified by reviewing numerous theorists writing about constructivist teaching practice. There was clear and consistent implementation of these four themes by both teachers in each lesson. Although I was not specifically looking for these themes in the lessons I think their emergence provides further support for concluding that integrating literature and mathematics is a constructivist practice.

There are several areas of overlap between constructivist and brain compatible theories of learning. The overlap between descriptions of constructivist classrooms and brain-compatible classrooms gives a clear picture of what people need to learn most effectively. For effective learning to take place, teachers need to offer: developmentally appropriate activity, learning in context, meaningful and purposeful exploration, a multimodal approach, opportunities and support for collaboration, and a positive learning environment. By planning with students' needs in mind, using the literature as a context for math concept development or introduction, offering engaging activities, and actively encouraging and engaging students while they were in the classroom, both teachers demonstrated application of constructivist and brain compatible theories through their lessons that integrated children's literature and mathematics.

Using children's literature was the key aspect of each of the six observed lessons which led to the lessons having the theoretical overlap. By selecting literature Elizabeth and Catherine put the math learning in context. They followed up the reading with developmentally appropriate activity, during which students were encouraged to approach the activities in a variety of ways. The careful selection of literature by the teachers, coupled with their insight into their students' responses to the literature led to the design of meaningful and purposeful exploration. In Elizabeth's class this was often the jumping off point to a longer term exploration; in Catherine's class the literature inspired many directions for exploration. Using literature created a positive learning environment. The students were eager to hear the stories and participate in discussions about the stories; the teachers were excited about sharing the stories with their students. Without the literature these math lessons would have been less connected with the students' construction of meaning.

Recommendations for Further Research

Both Elizabeth and Catherine describe their participation in professional development that was supportive and ongoing. I find myself questioning if the type and availability of professional development makes a difference in seeing how to integrate math into the curriculum; specifically how to integrate math and literature. What other professional development models would lead teachers to integrate literature and math? Another aspect of their professional development that was held in common was being placed in the role of students as a component of their learning. By experiencing math as a student, each teacher gained insight into what makes an effective problem and how to approach solving problems. Is this factor, placing the teacher in the role of student, particularly significant to changing math (or any other) teaching practice?

An area that bears further examination is the unique ways that each teacher chose to integrate literature and math. This difference could be related in some way to the professional development model each teacher experienced. It could also be attributed to the general teaching style of each teacher and the degree to which she integrated curriculum, so teaching style may be a focus of study. Teaching in two different grades, I wonder if Elizabeth's and Catherine's different approaches had something to do with the age of their students. Was Catherine able to integrate entirely around the theme of time because her students had so much more concept knowledge to carry out this in-depth study; or was this a decision more to do with teaching style? Another aspect of the decision to integrate either fully, or lesson by lesson, may also have something to do with the age and experience of the students. Another study might focus on examining integration strategies used by numerous teachers on the same grade level.

Interviewing Elizabeth and Catherine yielded many aspects in common; one in particular is early discomfort with teaching math. Would a teacher who entered the profession feeling comfortable with math come to decide to integrate math and literature? Would a teacher beginning his or her career with a positive outlook for math see a need to place math learning in a context such as literature? Those who enter elementary teaching comfortable with math, or with personal enjoyment of math is another population to investigate.

Both Catherine and Elizabeth are veteren teachers. Another avenue of inquiry to explore is teachers integrating children's literature and mathematics at various stages of development. What aspects of, or approaches to, teacher training influences when and how a teacher chooses to integrate curriculum? Is there a time in a teacher's accumulation of classroom experience that is more condusive to making curriculum changes such as those made by Catherine and Elizabeth?

This study focused only on lessons that integrate literature and math. A further area of study would be to observe other lessons taught by these teachers to examine in what ways using literature affects the design of the lesson. Does using literature as the beginning of the lesson lead these teachers to begin the lesson as if it were a literature discussion, or is the practice of an engaging lesson beginning true of all their math lessons. In other words what effect does the use of literature as a tool have on lesson design? The response to this question could affect the degree to which a lesson is constructivist and brain compatible as the beginning of the observed lessons were key to grounding them in theory.

Two is a small number from which to draw broad conclusions. Broadening the study to include more teachers would be helpful to draw more consistent conclusions about theoretical grounding for integrating literature and mathematics. There is no urban representation in this study (Elizabeth teaches in a suburban district, Catherine teaches in a rural district). Perhaps student population makes a difference to the outcome theoretically. Another variation to explore is teachers who integrate math and literature because they see a resource book or read about a lesson in a teaching journal. Replicating someone else's ideas for integration may affect the theoretical grounding of this strategy. Both Elizabeth and Catherine read about the idea of integrating literature and math, but both chose to design their own lessons based on their students' needs.

Examining integrated math and literature lessons for theoretical grounding could be done based on other authors' theoretical articulations. Another study might focus on one of the other theorists cited in Chapter two as a filter, or create a comparison study among several theorists to support identification of this strategy with a theoretical grounding. Further examination of the interrelationship between constructivist and brain-compatible theory is needed. This could be done by looking at theoretical articulations by other authors and by conducting other studies which include more classrooms and a wider variety of populations. Learning theories other than constructivism and brain-compatible learning could be identified to use as scaffolding for analysis which may provide theoretical support for integrating children's literature and mathematics.

I think that the different ways that Elizabeth and Catherine approached implementing the strategy of integrating literature and math also needs further exploration from a theoretical perspective. Looking at the approach taken by Elizabeth in particular, I think it is important to examine this strategy through both the lessons which integrate literature and math as well as the follow-up lessons. Is it enough to begin a math concept unit (for example, fractions) with literature to be considered theoretically grounded practice or does the literature, or follow-up lessons, play a larger role in determining theoretical connection? Another question this raised for me was "Can a strategy be a 'little' constructivist; is there some level or set of criteria that support an affirmative statement about determining that a strategy is theoretically grounded?" I found this question of degree raised also in brain-compatible theory with the element of choice. In the lessons I analysed, choices existed but they seem limited when compared to the definition of choice offered by Ross and Olsen and Lloyd. The element of choices bears further examination as does the question of degree of theoretical explication.

Two other studies which could support teachers who are integrating literature and math would be to analyze which of the published resources are theoretically grounded. An aspect of this study could be to analyze the books cited in publications for mathematical accuracy. Yet another study that bears consideration is a literary analysis of the series that have been published specifically to support integrating literature and math for both mathematical accuracy and literary qualities.

Another possible study is to look at the lessons teachers describe in publications through a theoretical frame. For example, in *Teaching Children Mathematics* many articles are published in which a teacher describes how she or he used a particular book to explore a specific math concept. It would be interesting to examine these lessons for themes in common to explore the role the literature played in each lesson and to what degree the lessons have theoretical integrity.

A broader area of study that could grow out of this one is to examine the role integrating literature has on making a lesson in any content area theoretically grounded. It was the use of literature that particularly linked each of the overlaps between constructivist and brain compatible theories. What other components of a lesson could be so essential to theoretical grounding, and what other theories might provide theoretical grounding for the integration of children's literature and mathematics?

Another study could be to explore or examine the difference between thematic approach to curriculum and integrated curriculum and/or interdisciplinary curriculum. These terms are used interchangeably in some literature, with distinction in others, but each term is unique. Where does the use of children's literature in teaching math really belong and does it make a difference which term is used?

Many aspects of assessment need further examination in relation to integration of children's literature and mathematics. One area of focus could be to look at individual student responses and achievement based on pedagogical treatment of this strategy (one book at a time or full integration). Another avenue to examine is what strategies or tools might be used to measure student acheivement and attitudes towards mathematics learning. Once a tool is identified, individual children and the effects integration may have on student attitude towards math and/or development of mathematical concepts could be examined. A focus on assessment and individual students would also allow for looking at the mastery element of brain compatible learning. Assessing how students are able to apply concepts learned in the context of integrated children's literature and mathematics lessons could further support grouding this strategy in theory.

Closing

This study addresses two research questions: How does a teacher come to implement integrating children's literature and mathematics as a strategy for designing mathematics instruction?, and Is integrating children's literature and mathematics a teaching strategy that is constructivist and/or brain compatible?. Based on the data collected I found that the two teachers who participated in this study each came to integrate children's literature and mathematics through participation in professional development. The integrated children's literature and math lessons I observed and analyzed met the theoretical criteria I selected for constructivism *and* brain compatible learning. Use of children's literature and the teachers' lesson design were key aspects of theoretically grounding lessons that integrate children's literature and mathematics.

In the process of answering my questions, I found many more. This study is a positive beginning in identifying a theoretical grounding for integrating literature and math, but as suggested by the above recommendations for futher research there are many aspects of this teaching strategy yet to examine.

Appendix-Sample Data Organizers

*Note-These are brief comments taken from my detailed field notes of each observed lesson. I completed these organizers for each analyzed lesson.

Lesson/Date-Phantom Tollbooth(in Progress)/ Time theme - first Observation 9/23 Teacher-Catherine

Brain Compatible Elements

absence of threat first visit happened when C. felt the class was comfortable with each other to have observer come – class is clearly for students (their work is everywhere, materials are out and accessible…) C. reads with great expression and interest, invites student participation (there is already rapport here), students are laughing
meaningful content student projects on time are intepreting their own history response to the story, Milo appeals and engages
choices students can read P.T. at their own pace, select where they work in the room, projects are open-ended, have guidelines but can do things in a variety of ways, timing is somewhat flexible (there are some scheduled blocks, but there are open times too)
adequate time this is an ongoing theme and the book is continually inspiring new directions (the puns list up on the board…) Students have deadlines for projects but they are generous; the daily schedule is adapted based on the response from the students (Something C. worries about, is she doing enough or is depth better?)
enriched environment wow- posters, student work in progress, wide variety of time books, beginning lists for students to raise questions, record information…time webs, topics kids want to study, sign post with 1 mile equivalent, vocabulary words, tools…
collaboration participation in the read aloud, webs, to do lists, discussion about rods, easy talk between students and the students with C., the desks are arranged in tables so they can work together (they are encouraged to check with each other)
immediate feedback the whole lesson is ongoing dialog and thinking aloud- open discussion allowed for questions to be quickly answered (calculator mix-up)

Comments:

Lesson/Date: first P.T. lesson observed (9/23) Teacher: Catherine

Constructivist climate

understanding that students' mathematical learning progresses at variable rates resulting in different levels of achievement math journals, discussion about rods, mile post in room, calculator use
acceptance that students travel different routes to gain mathematical understanding open questions, variety of tools for problem solving, facilitated discussion and encouraged collaboration
awareness that individuals hold different mathematical understandings clear in vocabulary discussion, some students are using the same words but have different or limited understanding/definitions-discovered in dialog and journals
knowledge that understanding is changeable. visible in the class, heard in dialog, redo of the timelines, 'to do' lists; more than knowledge it seems an expectation/assumption that understandings will change

Comments:
climate is sustained; kids are immersed in time concept, lit (P.T.) is only one avenue of exploration – the concept of time is everywhere, and there are a variety of ways to respond- it's broader than mere computation of time (although there is some of this for the timeline – (recognition of facts hour, quarter hour is already a skill) Is this (broader use/application) possible because students are older and have already learned concept of time?

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